Scientific Knowledge and Lay Cognition

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by
Stephen Hill

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Oh, they sit under big leaves, of course. We know that under all kinds of leaves in the forests and trees and moss, especially under mushrooms, there is a lot of life that we don't normally acknowledge. Trolls, elves, things like that. And I'm sure the butterflies know that too.

Roald Hoffmann (1981 Nobel prize winner for chemistry in reply to the question "Where do butterflies go when it rains?")

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Abstract

Recently psychologists have found it increasingly useful to view the layperson's attempts to reason about the world as similar to the processes utilized by professional scientists. This work attempts to examine this idea by discussing the nature of both science and everyday thinking.

A scientific realist philosophy of science, which emphasises the role of theory and method in human knowing, is chosen as the best framework for understanding the scientific dimension of everyday theories of physics and mind.

Everyday theories are taken to be vital cognitive entities used to embed an organism's immediate experiences within a broad explanatory framework. They are generated through a complex and dynamic retroductive method which utilizes an organism's total knowledge to guide and focus educated guesses about the causes of perceived phenomena. An individual's theory construction is further constrained by social and biological factors. Theorizing is viewed as a vital survival process that is firmly anchored in human nature.

This work concludes that there is no sharp distinction between everyday knowing and science, and that both are necessarily interrelated at a social level. Philosophies or psychologies that claim an independence of the two risk devaluing the knowing processes of the masses and thereby perpetuating an undemocratic and élitist society.

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The Changing Views of Science and Non-Science

Well, consider the very roots of our ability to discern truth. Above all (or perhaps should I say "underneath all"), common sense is what we depend on - that crazily elusive, ubiquitous faculty we all have, to some degree or other. But not to a degree such as "Bachelor's" or "Ph.D.". No, unfortunately, universities do not offer degrees in Common Sense. There are not even any Departments of Common Sense! This is, in a way, a pity. (p93-94).

*Douglas Hofstadter (from **Metamagical Themas**).*

In the course of this work I intend to examine the idea that people's everyday thoughts about the world are akin to theories constructed by scientists. Within psychology the metaphor of the layperson as a scientist has been central to the study of, what is sometimes called, 'naive science' (e.g., Fletcher & Haig, 1989; McCloskey, 1983a; Carey, 1985). Naive science is an umbrella term for a number of related research areas in which psychologists have compared laypeople's understandings of domains such as psychology, physics, and biology, with accepted scientific theories of those domains. Except for a few notable exceptions (e.g., Carey, 1985; Wellman, 1990) this research has not been unified into a single programme for studying the scientific aspects of everyday knowledge. The aim of this work is to, in some small way, lay a foundation for such a programme.

There are two basic steps that one must take in order to fruitfully develop this programme. The first involves observing, surveying, experimenting, and theorizing about the thoughts and ideas everyday people have about various worldly phenomena. This aspect of the everyday science programme has been initiated by several researchers studying quite disparate domains. The second involves characterizing what it is that *scientists* actually do. That is, we must study the scientific process itself (Fletcher & Haig, 1989). Without this perspective, researchers have no solid basis for judging the 'scientific-ness' of lay theories. This half of the programme remains seriously undeveloped by psychologists. Often they are willing to uncritically adhere to philosophies of science that have been learnt vicariously from exposure to undergraduate textbooks concerning the 'correct' way to experiment and present research.

In this introductory chapter I will provide brief summaries of both 1) research concerning people's everyday theories, and 2) present thinking in philosophy concerning the nature of science.

1.1. THE GULF BETWEEN SCIENTISTS AND LAYPEOPLE

On the surface it the difference between the thinking processes of laypeople and scientists seem quite obvious. Scientists are objective and rational, and use a lot of scientific jargon. Laypeople, on the other hand, are plagued by inconsistency and irrational, emotion-laden thoughts. However, these ideas are greatly complicated when we find, for instance, that Albert Einstein, perhaps the archetypal 20th century 'hard scientist', cast as a self confessed dilettante (Feyerabend, 1978) and that Isaac Newton, the founder of classical mechanics and cofounder of integral calculus, was in fact a keen magician, studying alchemy, apocalyptic texts, and other occult matters (Capra 1982: 51).

Take a quick first look at the question. When does a person stop being a layperson and start being a scientist? Are some people born scientists? Do you become a scientist when you finish your B. Sc. or when you read your first science textbook or when you do your first experiment? Indeed does a person who calls themself a scientist remain a layperson in areas that they do not specialize in or do they become some sort of demi-scientist? After pondering these questions for a while it becomes obvious that it is not possible to suggest that there is something *innately* different about scientists that distinguishes them from laypeople. To uphold the distinction between the two one can take one of two positions.

The stronger position is to argue that scientists *learn* to think about the world differently from the rest of us. That is, scientists can put their folk reasoning aside and plug into what I shall call a *rational epistemology* that is, a privileged way of thinking about the world. The idea that there are two types of knowledge, a common knowledge and a superior, intellectual knowledge, is a very deep seated one, and is shared by many cultures. For instance, in Maori tradition the knowledge of kaumatua, tohunga, priests, and high-status families was distinguished from that of ordinary people as being truer and purer (Best, 1923). In Ancient Greece great thinkers, such as Plato, made a distinction between opinion (*doxa*) and science (*episteme*) and placed greater status on science (Weisheipl, 1978). Even in Medieval magic there existed a distinction between 'folk magic' and 'intellectual magic' (Hansen, 1978).

The weaker of the two arguments is to suggest that, at rock bottom, scientists do not actually think differently from laypeople but that they exist within a particular institutional context that sets the two groups apart. In the course of this work I intend to argue for this point of view, and, based on that argument, establish why other points of view are potentially damaging for science itself and society as a whole.

This thesis, then, is about a collision in points-of-view. From one direction psychologists have recently begun to paint a flattering picture of the layperson - the ordinary person in the street, the primary school teacher, the carpenter, the checkout operator, the accountant, the caregiver - as someone who utilizes complicated cognitive resources in their dealings with the world. From the other direction, philosophers, historians, and sociologists of science have painted a more modest picture of the scientific process and the intellectual and rational capabilities of the scientist. To a large extent the scientist has come to be viewed as a fallible human being struggling to find out anything useful about the world in the face of prejudice and bias. As scientists become viewed as less rational and objective and laypeople's thoughts become viewed as useful and legitimate, the age old gulf between the intellectual and the intuitive begins to shrink.

In the course of this work I intend to exploit the metaphor of the layperson as a 'naive scientist' and the new views of science to outline a potentially fruitful direction of research for cognitive science which studies human knowing in scientific *and* everyday contexts. The following sections lay the foundation for this approach by examining research in the fields of 'naive science' and philosophy of science.

1.2. EVERYDAY THEORIES

During the course of this work I will ground my speculations on some of the work that has examined laypeople's everyday conceptions of various worldly phenomena. Much of this research covers only certain aspects of people's theorizing, and, thus, I will speculate as to how further aspects could be conceived. Within the framework that I sketch it will become apparent that a lot of the conceptions of people's theorizing that are common in contemporary research will need to be modified - at times in quite radical ways.

Much of psychology, especially the cognitive and social-cognitive approaches, has been concerned with how people think about the world. A particularly favourite pastime of these researchers is to show how people commonly make mistaken assumptions about things in domains as diverse as logic, statistics, and the motion of objects. Much of this research relies on an unspoken assumption that there are correct, scientific ways of understanding these phenomena. As I will make clear, this assumption is poorly thought out and often wrong. Psychologist's have examined the following domains of everyday thinking:

Physics, particularly mechanics (McCloskey & Kohl, 1983; McCloskey, 1983; Clement, 1983; Kaiser & Proffitt, 1984; Kaiser, Proffitt, & Anderson, 1985; Shannon, 1976),

Statistics, with an emphasis on Bayesian approaches (Kahneman, Slovic, & Tversky, 1982),

Logic, especially deductive logic (Johnson-Laird, 1983; Wason & Johnson-Laird, 1972),

Biology in terms of the development of concepts (Carey, 1985; 1988),

Social cognition based on attribution theories (Fletcher & Haig, 1989) and,

Psychology concerned with the theory of mind (Wellman, 1990; Forguson, 1989; Gopnik, 1990).

At times I will refer to these domains of research to elucidate my points of view. I will focus on intuitive physics and 'naive' psychology in the most detail and offer a brief summary of the research below.

1.2.1. Intuitive Physics

Intuitive physics research has concentrated on studying our perceptions of, and predictions about, the motion of objects. This research has revealed an apparent discrepancy between the intuition of the layperson and physical reality. It seems that people tend to adhere to an 'incorrect' *impetus* theory of motion rather than utilizing physically 'correct' *classical* theory inspired by Newton.

The research pioneered by Michael McCloskey and his colleagues was aimed at revealing whether laypeople understand and, more importantly, apply the following Newtonian principles:

1) Given no other forces acting on an object the object will travel in a straight line.
2) An object in motion stays in motion unless another force counteracts it.

To assess whether laypeople applied the first principle McCloskey, Caramazza and Green (1980) asked participants to predict the trajectory of a metal ball that breaks free from a piece of string as it is being twirled about someone's head. The participants were given a diagram (see figure 1.1) and instructions to ignore the effects of air resistance. The object actually moves in a straight line. The two dominant trajectories and the percentage of people adhering to them are shown on the diagram. Similar results were obtained using variants of this problem, such as predicting the trajectory of a ball fired out of a curved tube.

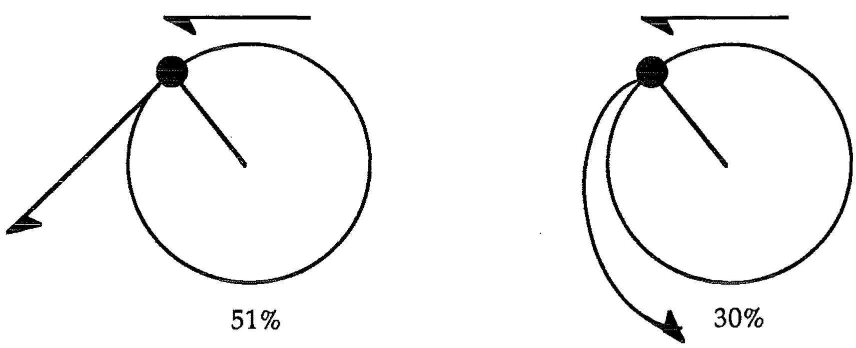

Figure 1.1
Trajectories produced by participants for a metal ball breaking free of a rotating line.

In order to ascertain whether participants adhered to the second principle McCloskey (1983b) asked participants to produce the trajectory of a metal ball that had been pushed off a cliff (again ignoring air resistance). In reality a metal ball pushed off a cliff would trace out a parabolic arc as it moved forward at a constant velocity while it accelerated downward.

McCloskey (1983b) found the following pattern of results:

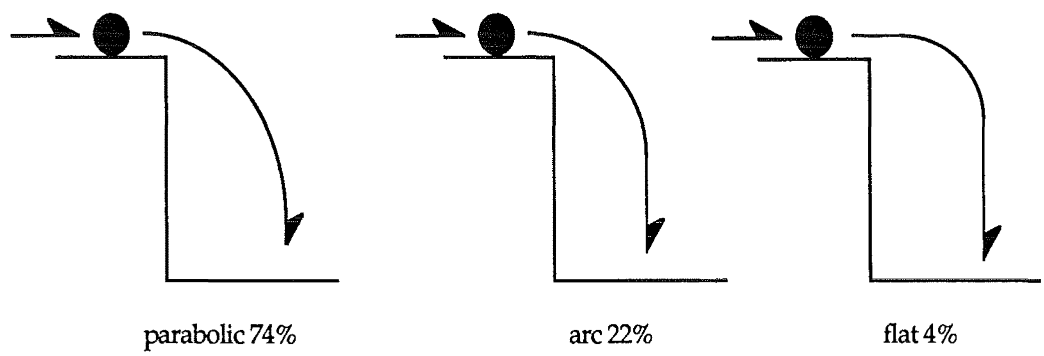

Figure 1.2
Trajectories produced by participants for a metal ball pushed off a cliff.

In a second group of experiments McCloskey (1983b) asked participants to produce the trajectory of a ball dropped from a moving conveyor belt or a moving aircraft. In reality the ball would follow the same parabolic trajectory as the ball pushed off the cliff. However, as can be seen in figure 1.3, the responses to these problems were somewhat different to those of the ball and cliff experiment.

After interviewing participants about their responses McCloskey (1983b) came to the conclusion that the majority of laypeople tend to adhere to a naive theory of motion which shares many of the ideas associated with a Medieval impetus theory of motion propounded by scientists such as Buridan , Philoponus, and Avicenna.

The basic principles behind such a theory are that: 1) the act of setting an object in motion imparts to the object an internal force or impetus that serves to maintain the object's motion, and that 2) a moving object's impetus gradually dissipates, and as a consequence the object gradually slows down and comes to a stop.

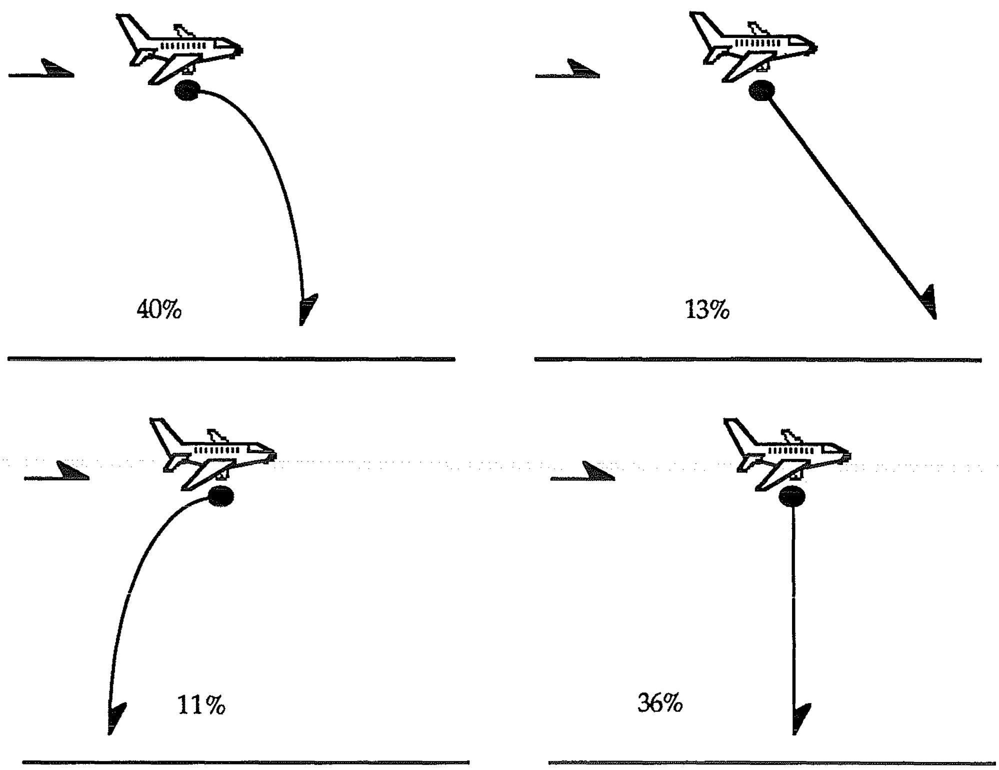

Figure 1.3
Trajectories produced by participants for a metal ball dropped from a moving aircraft.

McCloskey (1983b) found that although people seemed to adhere to the same basic theory there were differences of opinion over the following phenomena:

Path persistence
Many people believed that an object will continue to follow the path it has been forced into, such as a circular path caused by swinging a ball on the end of a rope. However, a few people believed (correctly) that an object once in motion must travel in a straight while still adhering to the (incorrect) idea of internal impetus.

Imparting an object with impetus
Some people believed only pushing or pulling an object will impart it with impetus; merely carrying an object and releasing it, as in the

aeroplane experiment, would not do it. Others believed that both carrying and pushing could impart impetus.

Interaction of impetus and gravity
Some people thought that objects with high impetus were unaffected by gravity. Others thought that gravity affected all objects in motion.

Dissipation of impetus
Some people believed that impetus is self expending, while others thought that impetus was reduced by friction. Some also thought that as curvilinear impetus dissipated the objects trajectory became gradually straighter.

Research into intuitive physics has become the archetype for studying laypeople's theories. However, intuitive physics has been studied in a relatively narrow way, concentrating on mechanics using textbook-like problems. It is clear that lay physics is probably a much wider theory encompassing topics such as light, sound, mass, and time.

1.2.2. Folk Psychology

Recently there has been increasing interest in laypeople's theories about the structures that are responsible for people's actions. This everyday theory has been called naive, common sense, or folk psychology. The literature covers two main areas: the development of this theory through childhood (see Wellman, 1990; Gopnik, 1990; Forguson, 1989), and arguments over whether the lay theory is actually a good basis for a scientific understanding of people's psychology (see Fodor, 1987; Stich, 1983; Kuhn, 1989; Horgan & Woodward, 1985; Bechtel, 1985; Clark, 1987; Graham, 1987; Graham & Horgan, 1988; Lyons, 1991). Researchers suggest that, of all lay theories, commonsense psychology is likely to be one of the most complex and accurate, because we are nearly always in contact with other people and are constantly interpreting and predicting their actions in order to make our lives more predictable and comfortable.

In essence commonsense psychology holds that people have beliefs and desires about reality and that these beliefs and desires are responsible for the actions of people. Lynd Forguson (1989) suggests that there are two main components of commonsense psychology: a *rational psychology* and a *commonsense realism*.

Rational Psychology

A rational psychology concedes that people have mental processes and that these mental processes are responsible for people's actions[1]. People's actions are viewed as being mentally rather than physically caused. Forguson suggests there are two basic causal mental states: *desiderative* states (or desires) and *epistemic* states (or beliefs). Desiderative states can be viewed as evaluations of epistemic states. A person may have a certain belief without it influencing their actions, but having a desire for the object of the belief is likely to, sooner or later, result in some sort of action to fulfil the desire. These mental states are sometimes called *propositional attitudes* because they are a statement about the world (i.e., a proposition) that has been understood in a certain evaluative way (i.e., the person has an attitude toward the state of affairs - they believe it is likely, or they would like to possess it, and so on).

Wellman (1990: Chapter 4) suggests that an adult's commonsense psychology maintains there are a number of structures, in addition to beliefs and desires, in a person's mind that are responsible for their actions. He suggests that adults have an elaborate understanding of the nature and relationships of perceptions (seeing, hearing, smelling), sensations (dizziness, nausea, pain), physiology (hunger, thirst) and basic emotions (love, hate, fear, anger), cognitive emotions (boredom, surprise, puzzlement), thinking (dreaming, reasoning, learning, remembering), beliefs (suppositions, expectations, doubts, and suspicions), desires (goals, wants, wishes, hopes, fears, and needs), intentions (decisions, plans, aims), and actions (hit, grab, search, attend to), within a

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[1] I use the word *action* rather than *behaviour* because behaviour is a term traditionally associated with the merely observable movements of an organism, whereas action includes an intentional component. That is, actions differ from behaviours because they refer to the intentions, goals, and beliefs of an actor (see Wellman, 1990: 99; Parker, 1989; Harré & Secord, 1972).

multidimensional framework which incorporates an understanding of internal-external activity, a conscious-unconscious continuum, and the stability of beliefs and desires. This view of people's folk psychology is much more complicated than that proposed by attribution theorists (Heider, 1958; Jones & Davis, 1965; Kelley, 1967) who think people attribute causes of people's behaviour based on a very few dimensions such as stability and control, and consensus, distinctiveness, and consistency (Kelley, 1973).

Commonsense Realism

Commonsense realism holds that 1) there is a single physical world common to all of us, and 2) that "the world is made up of objects, events, and states of affairs that are independent of the thoughts and experiences" that people have of it (Forguson, 1989: 15). Because of this, commonsense realism implies an appearance-reality distinction. Thus, it encompasses the idea that people interact with the environment based on their understanding or representation of it rather than the actual or real state of the environment. In this way commonsense psychology implies that different people may have different reactions to, and beliefs about, the same environment. Developmental psychologists are interested in the age at which children can 'stand in the shoes' of someone else who believes different things about someone in the same environment as them. In a Piagetian sense they seek to find the boundary between belief-desire egocentricism and the acquisition of a theory of mind. Research suggests this occurs around 3 or 4 years of age (see Wellman, 1990; Gopnik, 1990; Forguson, 1989).

1.3. PHILOSOPHIES OF SCIENCE

Today many scientists and laypeople have been led to believe that the issue of the nature of science is fairly clear cut and widely accepted. Nothing could be further from the truth. Philosophers, historians, sociologists, and other science researchers have become increasingly interested in the aims and products of science. Many ideas that people take as gospel truth about science have been challenged and thoroughly debunked in this vigorous and growing field, sometimes refered to as Studies of Science, Technology, and

Society (see Spiegel-Rösing & de Solla Price, 1977). As we have seen, psychologists studying the nature of people's everyday theories have been keen to contrast them with scientific theories and have pointed out the, often major, discrepancies between the two. Often, however, the scientific benchmarks that are used as a basis of comparison, assume a particular model of scientific rationality that is questionable. For instance, the assumption that people's failure to apply 1) *modus tollens* in reasoning tasks (Wason & Johnson-Laird, 1972 cited in Anderson, 1985), 2) Bayesian inferential statistics in social cognition (Kahneman, Slovic, & Tversky, 1982), and 3) ANOVA-like reasoning in social attributions (Kelley, 1967 cited in Gigerenzer, 1990) is an indication that their lack of scientific thinking relies heavily on the assumption that formal logic, Bayesian statistics, or Fisherian/Neyman-Pearson statistics, are typical of the reasoning procedures of scientists. As it happens the legitimacy of all of these claims has been challenged (see Thagard, 1988; Giere, 1988; Gigerenzer, 1990).

With this in mind I will very briefly outline three basic philosophies of science paying particular attention to what they have to say about science and non-science, and the nature of theories and scientific method. Because these characterizations are so brief I will make a number of generalizations which will not apply to some versions of the different philosophies. For a more detailed introduction to these philosophies see Giere (1988), Churchland & Hooker (1985), Nola (1988a), Bhaskar, (1986), Hacking (1983), Leplin (1984), Gergen (1985), Kuhn (1970), and van Fraassen (1980).

1.3.1. Empiricism

Empiricism is the philosophy of science that is largely responsible for most of our modern conceptions of science. Eysenck and Keane (1990: 1-2) briefly sum it up this way:

> * it maintains that whatever science is, it is *objective;*
>
> * this objectivity is considered to be exemplified by cool-headed scientists who record the facts about nature through *observation* and experimentation;

* it sees scientific knowledge as the result of the amalgamation of these facts into law-like *generalisations.*

According to this perspective, the scientist's task is no more complicated than measuring the temperature of boiling water repeatedly until enough "facts" have been amassed to form the generalisation, "All water boils at 100^{o} centigrade."

Empiricism is a philosophy of science that it deeply entrenched in the 17th and 18th century western culture (see Gardner, 1985; Capra, 1982; Hooker, 1985). Over these centuries there was a great debate between the rationalists, like René Descartes (1596-1650), and the empiricists, such as John Locke (1632-1704), David Hume (1711-1776), and George Berkeley (1685-1753), about the nature of human knowledge. The rationalists held that there were some basic *a priori* truths about reality that could be discovered by rational reasoning (such as arithmetic, geometry, and, of course, the mind), whereas the empiricists thought that we can only ever know things through our perceptions of them, and thus we can only trust the existence of the things we can see. This sort of thinking led to Hume's famous regularity view of causation and Locke's thesis that human knowledge was entirely learned, inscribed onto the blank slate, through our perceptions of reality. These ideas became instrumental in the genesis of 20th century behaviourism. Immanuel Kant (1724-1804) attempted to synthesize rationalism and empiricism with his extremely complicated *Critique of Pure Reason* (1781) silencing the debate by the density of his prose as much as with the genius of his ideas. After Kant, Auguste Comte (1798-1857), the founder of modern sociology, advocated a philosophy which held that the final goal of the human mind was to know the world through the mechanical, objective sciences as conceived by thinkers such as Descartes and Newton. This philosophy came to be called *Positivism* and soon intermarried with empiricism and rationalism to create the dominant philosophy of science and society for the next one hundred years. From the 1920's to 1940 logical positivism (or logical empiricism) was championed by the 'Vienna School' of thinkers. Their ideas have had a lasting effect on the nature of modern science and technology.

Empiricist Theories

Empiricists are of the opinion that theories are merely convenient structures for ordering generalisations of observations. So, for instance, they would say that my theory about Jan being an introverted person is merely a convenient way of gathering together all my observations of Jan being introverted. In particular, my hypothesis that there is a dispositional trait of introversion which causes Jan's introverted actions, is viewed by empiricists as a useful fiction. Empiricists would claim that there is no such functional or physical structure as a trait, only that talk of traits makes it easy for me to predict and explain Jan's actions. This view of theories is known as *instrumentalism* because it views theories and theoretical entities (such as traits) as instruments rather than realities. Contemporary neo-empiricists argue that it is necessary for scientists to believe that their theoretical entities are real in order to do science, but that we can never logically be commited to the this idea (van Fraassen, 1980).

The logical empiricist view of theories also states that good theories must exhibit a strict *deductive-nomological* structure. That is, all observations relevant to a certain theory must be deducible (in the formal logical or statistical sense) from the cluster of laws that define the theory. A theory is thus viewed as a cluster of objective observations of reality organized according to the objective process of formal logic. In this way logical empiricists thought theories could tell us the truth about a reality free of human subjective input and fallibility. Neo-empiricists like van Fraassen (1980) have rejected this syntactic view of theories in favour of a more sophisticated semantic (or set theoretic) approach. However, this approach continues to expound an appreciation of theories as abstract, formal entities largely independent of people's theorizing activities (see Hacking, 1983: Chapter 3; Thagard, 1988).

Empiricist Methods

In order for scientists to obtain and order objective observations empiricists hold that they must be trained in a special, 'rational' way to gather data and compile it into theories. Empiricists thus think there are ideal conditions for receiving information about the world. In particular, empiricists advocate a passive reception of information by someone who is clear-headed and devoid of spurious and biasing emotions (Gergen, 1979; Jaggar, 1989).

The ability to generalise and collate these various objective observations is performed by some form of logic. Early logical empiricist approaches advocated a syntactic approach utilizing foundational (or transcendental, or *a priori*) formal logic. This 'self evident logic' is reminiscent of the rationalism of Descartes and others. These empiricists appealed to the idea of pure knowledge - a timeless, universal knowledge free of social, emotional, and cognitive peculiarities.

Empiricist method was based around Reichenbach's differentiation of a *context of discovery* and a *context of justification*. Empiricists created a method known as hypothetico-deductivism (HD) in which hypotheses are tested by eliciting observations that are deducible from the hypotheses. This method is alive and well within the American Psychological Association's format for presenting research in journals. HD holds that the discovery of theories is a purely psychological phenomenon which occurs through chance and happenstance. John Tukey (1980) calls it the view of the lightning struck researcher. To the empiricists there is no logic to discovery and consequently it remains outside of the realm science. Those people who submit to the idea that there is a logic to discovery are said to commit the sin of *psychologism* (see Giere, 1988). The approach of neo-empiricists implicitly accepts this scheme by ignoring the task of generating models and theories (see Thagard, 1988: Chapter 3). Real science only comes into effect when the truth of a hypothesis is ascertained by seeing if predicted observable effects occur in an experiment. Karl Popper (1959) made the point that hypotheses could never be proved true using such a scheme, as a particular observation may be commensurate with any number of possible hypotheses. He suggested that a hypothesis could only be *falsified* - that is, if a predicted observation *did not* follow from a hypothesis then the hypothesis must be, in some way, flawed. As we shall see Imre Lakatos and Thomas Kuhn later discredited this idea.

Empiricism, Scientists, and Laypeople

Empiricism is a philosophy of science intertwined in the value system of the 17th and 18th centuries. Empiricism maintains that science functions best through a *rationalized epistemology,* that is, by using special types of logical (or near logical) reasoning. Science, thus conceived, is an enterprise carried out by educated, rational minds. Traditionally it was thought (and still is by many) that children, women, 'barbarians', and the working classes are too distracted by emotion and superstition to think clearly and calmly enough to be scientific. In the 17th to 19th centuries science itself became instrumental in 'proving' that women, children, and non-Europeans were innately unsuited to scientific thinking because of their anatomical and physiological deficiencies (such as having a small cranium and large pelvis). Today there is a persistence in establishing innate reasons for sex and race differences in thinking, especially in the study of hemispheric lateralization (Schiebinger, 1989: 189-213).

Empiricism continues to imply that *only* scientists can usefully know about reality. Hooker (1985: 191) elucidates the consequences of employing such a philosophy:

> widespread adoption of this position would be a historical socio-political mistake for humans, and not simply an intellectual one. It would be a mistake because it would reinforce a self-interested and cynical conception of social and political life at a time when we desperately need a more humane vision of its possibilities and more humane practice for our present tenuous civilizing institutions.

This sort of attitude toward empiricism started to bloom in the mid twentieth century and gave rise to alternative philosophies, such as scientific realism and constructionism.

1.3.2. Constructionism

For centuries there has been a significant school of thought that has held that knowledge is a construction of individuals and/or cultures and that there is no way of knowing whether there is any true knowledge or any fail-safe ways of acquiring knowledge (Nola, 1988b). The idea that knowledge is not absolute but relative to an individual, culture, classes, languages, species, and so on, has become known as *relativism* and the view that knowledge is constructed by the individual, culture, and so on, has come to be called *constructionism*. The two terms are related but not identical.

Constructionism started to make inroads into theories of science about the middle of the 20th century. The turning point in attitudes to science occured with the publication of Thomas Kuhn's book *The Structure of Scientific Revolutions* (1962). In this book Kuhn denied the truth of most empiricist beliefs. He argued, amongst other things, that there was no sharp distinction between observation and theory, that science was not a cumulative enterprise, that science does not conform to a tight deductive structure, and that the context of justification cannot be separated from the context of discovery (see Hacking, 1983). Similar ideas have bee n advanced by Paul Feyerabend, who argues there was no *one* scientific method, the Edinburgh school of sociologists of science (Barry Barnes, David Bloor, Stephen Shapin, and Donald MacKenzie), feminist researchers (Gergen, 1988), and post structuralist literary critics such as Derrida and Foucault (Parker, 1989).

Constructionist Theories

Perhaps the most radical break that the constructionists make from the empiricist view of theories is their claim that the sharp distinction between observation and theory is fallacious. They note, in a vaguely Cartesian manner, that there can be no such thing as an independent and objective observation. They claim that observations are always linked to some sort theoretical assumption, whether they are obtained as evidence for a theory or found via speculation based on a theory. Put simply, constructionists claim that we never consciously perceive things without fitting them into some sort of explanatory framework. Constructionists are advocates of the idea that we do not perceive something without a reason, prejudice, expectation, or opinion.

The second counterclaim that constructionists make against the empiricists is that theories are socially, not logically, constructed entities. A theory is taken to be an entity that helps to solve problems but which does not represent reality in any useful way. They suppose that theories and other cognitive constructs, rather than revealing anything about the nature of reality, are actually texts (or statements) that reproduce and instantiate the power relations between different social groups (Parker, 1989). As Gergen (1985) put it

> Research on social prototypes, implied personality theory, attributional schemata, the concept of intelligence, and the like do not, from the present stand-point, inform us about another world - namely an internal, cognitive one. Rather they might elucidate the nature of social discourse and thus raise interesting questions about the function of such terms in scientific and social life. (Gergen, 1985: 270).

Because of this approach constructionists emphasize the nature of paradigms or research programmes in science (Kuhn, 1970; Laudan, 1977). Although there has been much disagreement about the nature of paradigms (Kuhn is said to have used the word in 22 different ways [Masterman, 1970]), one can roughly characterise a paradigm as a set of shared values about the way a particular domain of interest (e.g. memory, money, or mechanics) should be studied. A paradigm thus supplies a *group* of scientists with a basic framework of the entities and processes that populate the domain.

A paradigm is a socially agreed upon way of dealing with a particular domain predicated upon values such as "pleasing sponsors, convincing colleagues, making claims plausible to many kinds of audiences, crafting careers, defending claims against challenge, and cooperating in teams and organizations" (Hornstein & Star, 1990: 423) as much as logic and perceptions of the so-called real world. A paradigm, thus, provides a set of culture-relative building blocks out of which more specific theories are constructed. Thus, advocates of the dominant cognitivist paradigm in North American social psychology will construct specific theories using building blocks such as *working memory, schemas, propositional networks* and so on.

In essence, a paradigm focuses the direction of research making metaphysical and methodological assumptions about the domain. These assumptions are rarely explicitly acknowledged by the scientists working within the paradigm. For instance, most North American social psychologists have probably never heard of the expression 'the cognitivist paradigm'. Theories thus, become implicated in what empiricists would view as biasing social expectations and assumptions.

For constructionists, then, a theory is simply a convenient way of dealing with puzzles that plague a particular group of people in a certain place at a certain time. What a theory reveals is the *way* a problem is dealt with, not the nature of the underlying reality.

Constructionist Methods

For the constructionists, scientific knowledge is created in a social and psychological environment rather than through some sort of transcendental, a-human logical process. There is the realization that knowing and knowledge are distinctly human *creations,* not discoveries of some disembodied 'pure understanding'. The universe does not need to have knowledge of itself floating about. The universe just is!

Constructionists go on to argue that humans are so saturated by cultural values, prejudices, and opinions that people can have no certain knowledge of reality. Indeed, the constructionist stand is a little depressing, claiming that we are inevitably sealed in some sort of social bubble which prevents us from understanding anything about the real world. All of our so-called scientific actions are exercises in making life comfortable for certain groups of people usually at the expense of other less powerful groups of people (see Giere, 1988; Pettit, 1988; Papineau, 1988).

In practise this view has resulted in Paul Feyerabend (1977) advocating an anarchist view of rationality which holds there is no privileged method for acquiring knowledge about the world. For Feyerabend, anything goes. All methods from shamanism, to tarot card readings, to numerology, to folk lore, to formal logic are equally good ways of beginning to construct knowledge. Feyerabend views empiricist dogma about scientific method as an overly narrow constraint on human knowing.

Similarly, the more rationally disposed Imre Lakatos (1970) criticised Popper's hypothetico-deductivism, claiming that a hypothesis can never be refuted solely on the basis of contradictory empirical evidence. This is because there a number auxiliary hypotheses surrounding a theory's core hypothesis that could be held responsible for an experiment revealing evidence contrary to tested core hypothesis. In this way the core hypothesis is protected from empirical refutation. Lakatos, himself attempted to introduce a rationalist solution to this problem (see Hacking, 1983: Chapter 8). Kuhn, however suggested that the construction and acceptance of theories was more due to, what Lakatos disparagingly called, 'mob psychology'. Kuhn rejected the view that scientific method was a case of a psychology of discovery and a logic of justification. For him, both parts of method were inextricably intertwined and equally subject to the nuances of human psychology.

Kuhn saw science as moving through a series of stages. During the period of *normal science* scientists subscribe to a particular paradigm, using it as a basis for relatively minor calculations, measurements, and applications. Minor anomalies may occur which cannot be understood under the present framework, but which are not thought to be important enough to alter the fundamental assumptions of the paradigm. However, when anomalies start to accumulate and begin to show important problems in the normal science paradigm a *crisis* occurs. After a period of disillusionment and confusion the whole problem suddenly becomes clear in light of a new set of basic concepts and ideas, that is, in light of a new undeveloped paradigm. With this *gestalt switch* (Kuhn's term for the sudden social and psychological insight that the problems make sense in light of a new framework of concepts) a *revolution* proceeds. A host of new ideas and ways of dealing with the domain are presented for researchers to work on. The cycle is completed and a stage of *new normal science* proceeds.

Kuhn made two important related points about this cycle. Firstly, concepts shared by different paradigms, such as mass, or oxygen, or memory, are said to be *locally incommensurable.* What Kuhn seems mean by this is that, although two paradigms may share the same name for a concept, each paradigm is actually refering to a different concept. Thus, scientists talking across paradigms may be totally baffled by their colleagues use of the term. Susan Carey (1988) gives an example of local incommensurability occuring between a mother and her four year old son. An adult's concept of a *baby* is related to the concept of *animal.* That is, a baby, is a very young animal. Young children do not share such a conception. For example, the young son of one of Carey's friends noted that although pigeons, dogs, people, and cats all have babies, worms merely have *short* worms.

> The essence of his account: babies are small, helpless, versions of bigger creatures, who because of their behavioural limitations, require the bigger ones to take care of them ... His idea seems to be that worms are so behaviourally bankrupt that there is no way for the small ones to have a limited repertoire relative to the bigger ones. Therefore, you would not ant to call them 'babies'. When pressed by his mother whether you could think of short worms as baby worms, he replied that you could if you wanted to, but then you might as well think of small rocks as baby rocks (Carey, 1988: 167-168).

Related to local incommensurability is the idea that the move from one paradigm to another cannot be viewed as any form of *progress.* Kuhn shows how, contrary to the empiricist view, a new paradigm does not usually explain everything its predecessor did. Indeed, Kuhn suggests that as much knowledge is lost as is gained when a scientific revolution occurs.

Kuhn, thus, showed that science is not nearly as neat and logical as had been thought. There is no steady accumulation of knowledge about the world through logical scientific method. Rather science chops and changes on waves of social and political upheaval, focusing on one problem at one moment, on another at the next. Sociologists of science, such as the Edinburgh school (Bloor, Barnes, and so on [Giere, 1988]), became concerned with how science mediates or intervenes in these political upheavals. Science, then, stops being the study of the real world and becomes a much more pragmatic social endeavour.

Constructionism, Scientists, and Laypeople

According to social constructionism, what sets scientists and laypeople apart is not the ability to generate valid knowledge about reality but social stratification based on power relations. Scientists and technologists are often viewed as being in league with the powerful political and social groups, producing knowledge and technology which claims to be objective and truthful but which is actually a tool for domination and oppression. Although Thomas Kuhn (1970) does not make such sweeping statements, his work has been used as a platform for the more vocal sociologists, feminists, and philosophers to critique the role of science in modern society and call into question the motivations of institutionalised Western science.

Despite the emancipatory tones of social constructionism it leaves itself open to a number of difficult problems, not the least being that it becomes difficult to take constructionism seriously in light of the (social constructionist) claim that we can never know if one type of knowledge is any more truthful than another. This leaves us in the paradoxical situation of admitting that social constructionism itself may not be true! Social constructionism paints itself into a corner. On one hand it claims that the production of all knowledge, including knowledge generated by so-called objective and rational means, is heavily influenced by social values and prejudices. On the other hand it systematically undermines this potentially emancipatory philosophy because social constructionism itself (being an example of socially constructed knowledge) cannot be known to be true and therefore must not be used normatively to initiate emancipatory social policy and action (see Pettit, 1988; Manicas & Secord, 1983; Parker, 1989). What is thus needed is a philosophy of science that does not self destruct while incorporating the important social and psychological aspects of the generation of knowledge. The philosophy of Scientific realism attempts to fulfil this role.

1.3.3. Scientific Realism

There are two central tenets to scientific realism: 1) that theoretical entities such as electrons and long term memory are real things, and 2) that our theories are, in certain respects and to some degree, actually about real things. Scientific realism came into being as a reaction to the instrumentalism implicit in both empiricist and constructionist views of science. That is, scientific realism is at odds with the ideas that theories are merely useful organizing structures for objective empirical observations or that theories are *solely* concerned with solving puzzles relative to a particular group's needs and goals. As the rest of this work will be heavily based on a scientific realist philosophy I will attempt only the briefest of characterizations here.

Scientific Realist Theories

Scientific realists agree with many of the claims made by social constructionists with regard to theories. They accept that there is no clear distinction between theory and observation (although some observations of the world are less theory-laden than others), and thus that empirical evidence in and of itself is insufficient for establishing the truthfulness of theories. They agree that social processes have a vital role in the generation of knowledge, and they concur with the idea that we can never create theories which are completely accurate representations of reality. They also hold that the contexts of discovery and justification are intimately connected and neither purely logical nor totally intuitive.

However, unlike constructionists, scientific realists focus closely on the nature and structure of theories, claiming that they are extremely complicated human creations that successfully attempt to represent reality with ever increasing accuracy. They believe that truth is an important, though unobtainable horizon concept which guides and focuses our theorizing.

Scientific realists substantiate these claims in a number different ways. I believe that the best type of scientific realism, Evolutionary

Naturalistic Realism (ENR), provides the most convincing substantiations (see Hooker, 1985; Giere, 1988). Essentially ENR claims that human beings, through processes of biological evolution and social change, have acquired the essential physiological and functional structures for creating reasonably accurate knowledge of reality. ENR embraces the idea that the ability to gain this knowledge is a natural ability of all human beings. This is not to say that we humans do not, at times, produce fanciful or inaccurate knowledge, only that we have evolved (and continue to evolve) the *capacity* for understanding many of the deep causal structures at work in reality. For scientific realists, theories that postulate real but theoretical (that is, unobservable) entities, are the vehicles for all our public knowledge about the world (Haig, 1991b). Without theories that grasped some essential aspects of reality, argues the realist, human beings could not possibly survive as they have.

Scientific Realist Methods

Evolutionary Naturalistic Realism takes method to be the most important feature of science (Haig, 1991b). Our knowledge of the world is generated by both evolutionary and revolutionary processes. Scientific realists do not see scientific method as a purely logical algorithm for acquiring true knowledge, nor do they see it as being entirely due to social and institutional processes. For the scientific realist, knowledge is created through biological, social, and individual contexts.

Realists view the generation of knowledge as roughly *retroductive* in nature. That is, they view knowledge as being generated by explaining the underlying causes of types of phenomena based on the experience of a number of instances of the phenomena. In other words, retroduction is the process of making educated guesses about why things happen. Retroduction is much less rigorous than formal deduction or induction and, in order to be viewed as a valid means for generating knowledge, the realist is required to investigate the cognitive and social constraints on the educated guesses it produces. Retroduction, then, rather than being a type of formal logic, is best understood as a pattern of reasoning, whose nature is illuminated by the interdisciplinary study of psychology, sociology, biology, and other disciplines.

Scientific Realism, Scientists, and Laypeople

Scientific realism, especially in its form as ENR, views all humans as capable of generating important knowledge about the world. Theory generation is a human capacity not a learned skill. Scientific realism does not deny that some groups of people may be better at generating accurate knowledge about the world than others, only that everybody has the potential to do so when given the freedom to do so. Thus, ENR is a philosophy with a normative component. That is, it is a philosophy that advocates the view that we need to restructure our institutions to better enable people to create theories of increasing accuracy. It is a philosophy that views oppressive institutions as standing in the way of creating a just world. Indeed, it implies that the freedom of knowing is vital for our collective survival, and that restrictive or indoctrinary institutions will endanger this process.

Clearly scientific realism exists on a different plane to the empiricist view of a value-free and humanless science. Throughout the rest of this work I will use ENR as my characterization of science. By doing this I hope to show that the theoretical world of the layperson is, in many respects, the same as the theoretical world of the scientist. And, perhaps more importantly, I will outline how scientific and everyday knowledge are inextricably interconnected.

1.4. STRUCTURE OF THIS WORK

The rest of this work will discuss a view of cognition which, I believe, is adequate for discussing the reasoning processes of both laypeople and scientists. In Chapter 2 I examine theories as explanatory cognitive entities. I discuss issues such as, the relationship of theoretical knowledge to other types of knowledge, the structure and taxonomy of theory-like structures, and the purposes theories serve.

Chapter 3 examines the creation of theories by a natural retroductive-explanatory-inferential method. Theories are examined as dynamic structures evolving through contexts of generation, development, and appraisal. The realist approach to method favoured in this chapter provides a basis for viewing lay knowing and science as similar activities. This is contrary to the views of some researchers who suggest that laypeople's theories, while being similar in structure to scientific theories, are actually constructed by different processes of reasoning.

Chapter 4 puts theorizing in a wider social and evolutionary context. I examine the idea that theorizing does not go on 'in people's heads' but through a whole host of social and physical activities and exchanges with our environment. I attempt to expose the layperson-scientist distinction as being due to social stratification rather than a difference in rationality.

Chapter 5 concludes with a brief overview of the work. It ties the threads of the previous chapters together in order to outline a basic framework for the 'naive science' programme.

2

Theories

It's impossible to say a thing exactly the way it was, because what you say can never be exact, you always have to leave something out, there are too many parts, sides, crosscurrents, nuances; too many gestures, which could mean this or that, too many shapes which can never be fully described, too many flavours, in the air or on the tongue, half-colours, too many. (p144).

*Margaret Atwood (from **The Handmaid's Tale**)*

In Chapter 1 I showed that a discussion of *theories* is central to all of the major philosophies of science. Theories are heralded as the vehicles for scientific knowledge. Psychologists concerned with the study of the 'naive science' use the metaphor of the layperson as a scientist to argue that laypeople also utilize theory-like structures. However, it remains to be seen exactly how far we can stretch the metaphor with regards to theories. In the course of this chapter I will present a way of conceiving theories, whether scientific or everyday, as a mental representation used to help us navigate about our physical and social environments. Once I have outlined what I take a theory to be I will examine what, if anything, distinguishes theoretical knowledge from other types of knowledge. I will close with a discussion about the features of scientific theories that may distinguish them from our everyday theories about the world.

2.1. WHAT ARE THEORIES FOR?

Let me begin by giving a crude characterization. A theory is a tool for surviving in a changing environment. It provides a person (or higher animal) with a way of locating immediate (perceptual) experiences in a broader and deeper context of reality. By establishing how an event comes about or what it is related to (that is, by *explaining* an event) we are in a better position to predict what is going to happen next (or what has just happened) and are better able to ready ourselves for an appropriate survival-enhancing action. Put simply, theories give us the drop on reality. But theories are not just for helping us to avoid unfavourable events - the picture painted by such a conception of the use of theories would be of humans continually on the run from danger. Theories also give us the capability to control events and, more importantly, they enable us to intervene in the world to alter the structures and powers of its entities.

Theories, as survival enhancing mechanisms are, thus, likely to be the result of evolutionary processes. Evolutionary theories hold that an organism evolves reciprocally with its environment; that is, a creature simultaneously alters and is altered by its environment. In order for an organism to survive it must develop features for survival. These features include not just gross physical features, such as a heavy fur coat to protect against the cold, but also various behaviours and cognitive processes, such as nocturnal food gathering and large memories for buried seeds.

In many animals, including humans, it is optimal to develop complicated nervous systems that can accurately depict the basic nature of reality, such as a perception of depth or an ability to understand and interpret the behaviour of other organisms. It is this ability to depict important aspects of reality which results in the construction of scientific and everyday knowledge. Our survival to this point in history is an indication that what we believe about the world is reasonably accurate and useful (although see O'Hear, 1989, for a contrary viewpoint). Thus, the natural, evolved processes that we possess for forming these accurate beliefs exist and can be utilized to improve our understanding of reality.

2.1.1. What do Theories Tell Us About Reality?

Theories explain laws which are generalizations of a number of observations (Thagard, 1988). This particular view of theories is usually closely associated with the logical positivist philosophy of science. This philosophy maintains that each of the lower levels of this hierarchy should be deducible from the higher levels (the deductive-nomological theory of explanation), that theories are merely tools for describing groups of observations (instrumentalist view of theories), and that observations are privileged types of information which provide us with the only sure foundation of knowledge (foundationalist theory of knowledge). All of these theses have been called into question, and, I think, thoroughly debunked. The theory-law-observation hierarchy however remains a useful one. What it provides us with is an idea of theory as an entity which attempts to explain patterns of real world phenomena. To a creature that based all of its understanding of the world on basic sensations the world could appear to be of a multitude of dissimilar and unrelated things. No two events or objects would appear to be the same and the creature would have no basis for acting in a meaningful or predetermined manner. We do not perceive it this way because we have a capacity to generalize (that is, cluster certain temporally or physically similar observations together) based on fundamental biological knowledge. These generalizations are further clustered by unpacking deeper similarities through the process of explanation. Theories, then, provide us with an entrance into the unobservable world of reality. Following Wellman (1990), I believe they tell us three basic things about this reality:

1) A theory tells us about the nature, scope, and kind of entities that are purported to exist in the domain that it covers. More technically, a theory specifies our *ontological commitments* (what exists) and *ontological distinctions* (how entities differ from each other). This knowledge actually defines and characterizes the domain in question by establishing how we categorize and relate to relevant phenomena. A theory, then, provides us with an *ontology*.

2) A theory tells us how these entities relate to each other. That is, a theory *explains* the entities. Often this involves positing the causes of events or things. Thus, a theory provides us with an *explanatory framework*.

3) A theory tells us (often implicitly) how we should go about interacting with the phenomena in the domain in question. That is, it provides us with a basis for further developing ideas and plans of action for dealing with the domain. In this sense a theory provides us with *methodological constraints.*

In sum, theories can be viewed as 'extending our perception', of giving us a view of the reality beyond our narrow sensorimotor window. With them we can try and understand the hidden causal mechanisms at work in the universe, mechanisms that are inaccessible because they are intangible (such as cognitive mechanisms or gravity) or too small, too distant in place or time, or too dangerous (such as tectonic plates, or the environment in the cretaceous period) to get at.

2.1.2. Theories and Reality

A scientific realist philosophy of science holds that our best scientific theories tell us something about the nature of the reality that they are about. Many scientific realists hold that the theoretical (that is, unobservable) entities postulated by our scientific theories actually refer to real but unseen things. Most scientific realists believe that today's scientific theories have made considerable progress compared to yesterday's theories. This approach to theories raises some interesting questions for cognitive science: Do the everyday theories of laypeople achieve this level of 'truthfulness', and, if so, how can we support such a contention?

There is no doubt that everyday theories are useful in the environment in which they are intended to be used. For instance, Holland et al. (1986) note that nature does not punish us for using our intuitive theory of mechanics because, considering the context it is used in, it is actually a very useful approximation of the movement of objects.

> impetus theory as a set of propositions is a better q-morphism [mental model] for the world we live in than for the idealized world Galileo and Newton had in mind. Objects that operate under constant conditions of friction do

> indeed behave as if they possessed an impetus subject to gradual diminishment.
> (Holland et al., 1986: 209)

However, many anti-realist philosophers contend that a theory's usefulness is no indication of its accuracy in depicting the structure of reality. My inclination is to say that if a theory helps us to predict, explain, intervene, or control real-world phenomena, then the theory *must* capture some of the relevant aspects of that reality; therefore, laypeople's everyday theories *are* intended to give realistic renderings of the world. But, as with all claims this bold, there needs to be a proviso. People's everyday theories are real only in certain respects and to some degree, and many *scientific* theories are often real in many more respects and to a much greater degree.

Giere (1988) notes that anti-realist philosophers often argue that we cannot know that our theories are refering to actual structures in reality because historically science has utilized such concepts as ether, phlogiston, and caloric as useful theoretical concepts and yet they have been later found to be non-existent (see for example, Laudan, 1984). Giere (1988: Chapter 4) introduces the idea that the map of reality our theories propose is similar to the relevant aspects of the real world in specified *respects* and to specified *degrees.* A theory may differ from reality to varying *degrees* in that it describes the correct type of underlying structure, but gives it too much or too little power to cause a certain effect. For instance, we might propose a theory about the spin number of a certain sub-atomic particle. Later we may find out that the spin number is incorrect but that the particle itself is a genuine entity. A theory may differ from reality in some *respects* because the structure it postulates is actually different in some significant way. For instance, scientists in the 19th century thought that light waves travelled through space by propagating along an elastic substance known as ether. It is now known (or, should I say, widely accepted) that ether does not exist and that the ether theories were not correct in that respect. However, there are many respects in which electromagnetic radiation *is like* a disturbance in the ether (Giere, 1988: 107). In a similar way laypeople's understanding of the nature of 'force' as impetus-like, shows that the commonly held lay theory of motion differs in significant respects to the classical theory of mechanics, but it still captures important aspects of reality. Indeed, the use of the classical theory of mechanics to estimate the behaviour of objects at extreme velocities results in 'naive errors' in light of the more real general theory of relativity. I think the same argument can be extended with regards to the recent debates about the usefulness of employing folk psychology in a scientific study of thought and action (Graham, 1987; Fodor, 1987). Beliefs and desires can be viewed as theoretical entities that capture some of the vital aspects of human mental life even if they prove to be only loosely related to patterns of neural activity or sophisticated cognitive functions explicated by neuroscience and cognitive science. Beliefs and desires will still contain rigourous enough information about real life for laypeople to effectively survive in the social world (see Graham & Horgan, 1988).

Understood this way we can view laypeople's theories as approximately true even if they hypothesize entities or relationships that scientists have long since abandoned.

2.1.3. Theories as Mental Representations

Within cognitive science the mind is typically viewed as possessing *internal, mental* representations. That is, we are supposed to have something 'in our heads' that is separate from the external reality it depicts. This can perhaps be viewed as an instance of the old Cartesian dualism (Bechtel, 1988a); the view that there is a mental world independent of a physical world. In this view a theory can usefully be thought of as a mental representation.

This, however, is by no means the only view of representation. There are those who believe that talk of internal or mental representation is in error, and that there is no intermediate level between public speaking about the world and neurophysiological events (e.g., Harré, 1988).

Hacking (1983: 103-146) claims that human beings can usefully be defined as representers, yet he characterizes representations as public and external *not* private and internal.

> When I speak of representations I first of all mean physical objects: figurines, statues, pictures, engravings, objects that are themselves to be examined, regarded...
>
> Representations are external and public, be they the simplest sketch on a wall, or, when I stretch the word 'representation', the most sophisticated theory about electromagnetic strong, weak, or gravitational forces. (Hacking, 1983: 133).

In this work I prefer to think of theories as mental representations and yet, to a large degree, I agree with Hacking's characterization of representation. First of all, I agree that representations are importantly grounded in reality. That is, that not only are our representations about real things, but, that regardless of how abstract they may seem, they are also constructed by reference to things we experience through our senses (Johnson, 1991). This is a point to which I return in Chapter 4. Second, in the tradition of John Dewey (cited in Hacking, 1983), I dispute the false dichotomy between mental and physical, internal and external, and knowing and doing, that constitutes the basis for much of modern cognitive science. I also agree with Hacking and Johnson's view that the emphasis on abstract thinking about reality (and the concomitant ignorance of action and body) has resulted in an idealist flavoured philosophy of science, that concedes that we may not know anything useful about reality. Mental representations are, thus, a complex of evolutionary, cultural, and individual processes of bodily interaction with the environment. They are *of* the real world, not separate from it.

2.2. THE NUTS AND BOLTS OF THEORIES

2.2.1. The Structure of Theories

Following Paul Thagard (1988) I feel it is useful to conceive of theories as implicit entities that arise as a result of the connection of concepts (including theoretical concepts), rules, and problem solutions. Thagard (1988: 40) gives a rough written conceptualization of the wave theory of sound as follows:

Wave theory of sound:

Concepts: sound, wave.

Theoretical concept: sound-wave.

Rules: If x is sound, then x is a wave.
If x is sound, then x is a sound-wave

Problem solution: Explanation of why sound propagates.
Explanation of why sound reflects.

This example gives us some idea of the nature of the different components of a theory: concepts, problem solutions, and rules.

Concepts

A concept (or theoretical term) is a characterization of a particular entity, relationship, or event. The concepts embedded within a theory are tightly linked together in an interrelating web. They gain their meaning through their relationship with other concepts. That is, their meaning is a function of their interconnections rather than stemming from a dictionary-like definition of necessary and sufficient conditions (Wellman, 1990; Thagard, 1988: 70). Concepts are interconnected in two main ways: First, every concept fits into a hierarchy of superordinate and subordinate relationships (by way of *synchronic categorical* rules) and, second, every concept is associated with other concepts with which they are similar (whether perceptually, causally, functionally, or coincidentally) (see Medin, 1989) by way of *synchronic associative* rules (Holland et al., 1986). The *rules* which are associated with the concept do not define it, at most they merely roughly characterize it. Rather they link concepts together in a coherent network of associations and relationships. This, I believe, is what most cognitive psychologists mean when they talk about *schemas:* a massive network of related concepts (see Schank, 1982). For instance, the concept of a dog would be connected with subordinates such as alsatian, collie, and poodle, and superordinates such as mammal, animal, and living thing, as well as being associated with concepts such as pet, bone, bark, and so on.

Simply put, a concept is a set of pointers to other concepts within a theoretical framework (see Medin , 1989).

One particularly important type of concept is, what Thagard terms, a *theoretical concept*. Here the term theoretical concept is used to refer to a concept of a postulated or unobservable entity such as impetus, an electron, a belief, a black hole or a sound-wave (see Hacking, 1983; Haig, 1991c). Scientific realist philosophers of science often point out that good theories will nearly always invoke theoretical concepts to unify data and provide explanatory power. For instance, by postulating the existence of a sound-wave scientists were able to understand why sound reflects and propagates, and thereby provide a foundation for constructing all sorts of acoustic technology.

Problem Solutions

Problem solutions are procedures that can transform one particular situation into another. Typically we start with a set of initial conditions (which are problematic) and we seek to show how we can change conditions to reach a desired goal state. There are two types of related problems:

1) In the standard problem solving literature the goal of the system is an unattained but desired state of affairs. At first a problem is typically only vaguely understood. As the problem solution is gradually created the initial conditions, the desired goal state, and the discrepancy between the two are more fully comprehended. This is known as the constraint-composition, or constraint-inclusion, view of problem solving (Haig, 1987; Nickles, 1981) and will be discussed in further detail in Chapter 3.

2) The second type of problem is what Thagard calls an *explanation problem*. In an explanation problem the goal state (known as the *explanandum*) is already known to exist (although, like a standard problem, it may only be vaguely conceived).

A problem solution thus consists of a list of initial conditions, a list of goal states, a list of associated relevant concepts, and a list of (diachronic) effector rules which detail what actions are necessary to solve the problem. Although this characterization of a problem solution seems to be quite skeletal, in practice it shows how a problem solution in fact is a complicated representation of a changing environment, and thus must include information as to the structure and powers of theoretical entities.

Problem solutions are not only useful for solving problems akin to the one that they were first generated to solve, but importantly, they can be used as 'models' for understanding phenomena in other domains that often bear little superficial similarity to the source domain. That is, problem solutions can be used as *analogies* for solving problems in domains where there is reason to believe that states of affairs share some structural similarity (see Harré & Secord, 1972; Keat & Urry, 1975). Often a particular problem solution (for instance, the model of the hydraulic pump) is postulated as an underlying, and as yet unseen, structure responsible for certain behaviour (such as blood circulating about the body). Thagard (1988) hypothesizes that when a problem solution for one specific domain is used to solve a problem in a distant domain, the common procedure is abstracted out of the two problem solving situations and compiled as a problem *schema*.

In traditional cognitive psychology problem solutions have been called *algorithms* if they are step by step procedures for attaining a specific, correct goal state, or *heuristics* if they are general rules of thumb that do not always work (see Anderson, 1985: Chapter 8). From Thagard's point of view an algorithm is a problem solution created to solve a very particular (and typically very well conceived) problem (that is, it is pragmatic). A heuristic however is more like a problem schema (that is, is more syntactic), an abstraction that is more domain general and also more likely to result in an inconclusive or erroneous state. Heuristics however are often all we have available to begin to solve a novel problem.

Rules

Although rules actually comprise concepts and problem solutions, theory generation often involves the creation of independent rules that join previously existing concepts and problem solutions. For instance, in the characterization of the wave theory of sound at the beginning of this section, Thagard (1988) list two rules which join together old concepts: *if x is a sound, then x is a wave* and *if x is a sound, then x is a sound-wave.* Of course, once these rules have been generated and appraised we can then view them as part of the relevant concept (in this case the *sound* concept).

A theory composed of these structures and processes can at once represent and characterize a host of entities, their powers and relations to other entities, and can supply us with procedures for dealing with these entities when we experience them in our environment. A theory so conceived is obviously a dynamic structure constantly undergoing change and deeply and inextricably embedded within an organism's total knowledge. It is with this thought in mind that we move onto the next section which explicates the possible 'external' relationships between theories and theory like structures in the individual's mind.

2.2.2. The Organization of Theoretical Knowledge

The picture I hope to be building up is that theories, rather than being distinct, explicit structures, are patterns that arise when a group of related concepts and problem solutions are activated together through hierarchical (subordinate/superordinate) relations and associative relations. In this picture theories overlap substantially in the individual's knowledge base to form a more or less coherent world view. That is, theories from different domains borrow and share concepts to make themselves coherent. In fact, the inextricable interconnectedness of our theories is vital for survival. Often when we are dealing with a problem it requires all of our cognitive resources to cope (see Hooker, 1975 for a discussion of these issues in philosophy of science). For instance, crossing a river with a group of colleagues may involve knowledge about biology, physics, social processes, language, and mathematics. Despite the interconnectedness of our theoretical knowledge it is still useful to outline different structures and relationships that exist. Knowing that we think with a skull full of cognitive soup may sound delightfully holistic but it gets us nowhere in trying to establish the nature of human cognition.

Theoretical knowledge and knowledge processes can be usefully understood as being made up of three types of structure: framework theories, specific theories, and mental models (Wellman, 1990: Chapter 5). Figure 2.1 shows how these structures relate to each other.

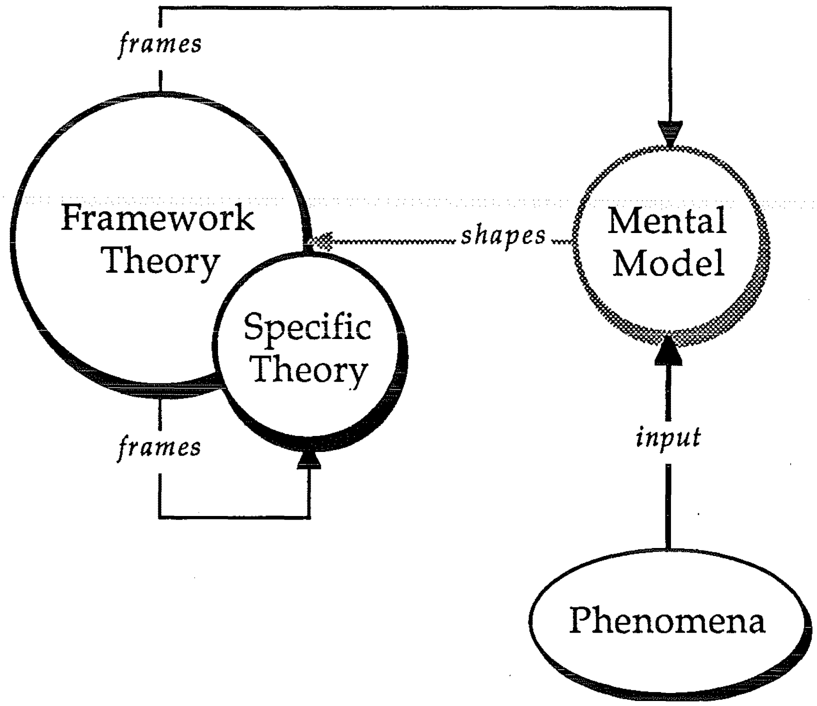

Figure 2.1
The relationship of framework theories, specific theories, and mental models.

Framework Theories
A *framework theory* or global theory is the cognitive equivalent of a paradigm, research tradition, or research programme. That is, an framework theory provides us with the basic, broad, and deep assumptions about a domain of knowledge. They are so called because they provide a frame for the development of specific theories within the domain in question. Each framework theory tells us what basic entities and processes are allowed to exist in specific theories (specifies our ontological distinctions and commitments), how these entities interact with each other, what events are causally, statistically, or merely accidentally connected, and what their powers are (provides a causal/explanatory

framework). Moreover, framework theories tell us how we are likely to interact with the phenomena within the framework theory's domain. That is, they *constrain our methodology*. For instance, Hooker (1975) notes that global theories specify 1) what is and is not observable, 2) how to describe those observations, 3) the conditions under what is or is not observable, 4) the instrumental means by what is measurable is measured, and 5) the reliability of these measures.

In terms of the theory of method that will be outlined in Chapter 3 framework theories provide us with the methodological constraints that guide the creation and appraisal of specific theories. Thus they provide us with four types of regulative principle (see Haig, 1987; Haig, 1989).

1) *aim-oriented principles* constrain our theorizing by considering our need for accurate or useful information (also see Kruglanski, 1989, 1990). If our aim is only to supply an answer of little importance to an acquaintance we are unlikely to spend a great deal of time developing a deep theory, whereas we may expend many resources constructing a theory whose application may be a matter of life or death.

2) *heuristic principles* constrain our theorizing by supplying us with rough rules of thumb (that have been abstracted from their regular usage in other theorizing experiences) and which provide directions for understanding certain phenomena. Examples of heuristics would include the *difference reduction method, means-ends analysis,* and the working *backward method* (Anderson, 1985: 205-220).

3) *metaphysical* or ontological *principles* constrain our theorizing by allowing only those relationships and those entities that are part of the basic premises about the world to be used in the generation and appraisal of theories.

> Thus, Cartesian particles can only interact by contact, not by action-at-a-distance. Entities, within Marxist research tradition, can only interact by virtue of the economic forces influencing them.
> (Laudan, 1977: 79 cited in Wellman, 1990: 126).

4) *epistemic values* are those values that we use to appraise the usefulness and accuracy of our theories. Researchers have suggested many *general values* which scientists use to appraise theories such as simplicity, fertility, existential depth, and empirical adequacy (I will discuss these in some detail in Chapter 3). However, framework theories, through their domain specificity, have a record of the weightings that we place on the various values for theories at particular stages of development within a particular domain. So, for instance, different values would be used to appraise the plausibility of a nascent theory about the motion of a ball fired out of a tube, than would be used to appraise a developed theory about the mental state of your best friend.

It is important to note that the ontology, explanatory framework, and methodological constraints (composed of aim-oriented, heuristic, metaphysical principles, and epistemic values) are not separate 'routines' in the mind, but rather that they come about through the spreading of activation through a complex of concepts, rules, and problem schemas.

Susan Carey (1985) suggests that the average educated Western adult possesses something of the order of a dozen framework theories, covering such domains as psychology (mind), physics (probably mechanics and matter), social sciences (political economy, sociology, history), religion, and biology.

Framework theories do not change quickly, as they provide a secure foundation with which to interpret the world. Indeed Imre Lakatos (1970) suggests that research programmes will not change until a successor exists, such is the importance of a basic metaphysics. As Wellman (1990) and Kuhn (1970) note framework theories are not likely to change based on seemingly contradictory empirical evidence as too much time and effort has gone in to constructing them. Framework theories are of such stature that their central tenets are reasonably impervious to contradictory empirical evidence. Only major deficiencies with criteria such as consistency, scope, fertility, and unifying power can eventually cause an framework theory to crumble (see Wellman, 1990; Fletcher & Haig, 1989).

Just as we can view problem schemas as abstractions of the commonalities of a number of problem solutions, framework theories can be viewed as abstractions of the shared features of a cluster of similar specific theories. Indeed problem solutions are more likely to be found in specific theories and problem schemas are more likely to be associated with framework theories. In his cognitive approach to philosophy of science Ronald Giere (1988), following the ideas of van Fraassen (1980), views framework theories as being constituted of clusters or families of specific theories[1] which are joined, not by logical connections suggested by empiricist philosophers, but by *relations of similarity*. For instance, he suggests that two specific theories may cluster together because one is an approximation of another (Giere, 1988: 86).

Similarity is an important but extremely loose concept (see Medin, 1989; Giere, 1988). In Thagard's computational model of theories, theories are similar if they share concepts or problem solutions at some level of generality, or are joined by rules. Theories can be joined by categorical or associative relationships. That is, specific theories are similar if activation spreads from one to another. Moreover, the similarity of any two theories will change as we reconceptualize the domains covered by the theories. For instance, someone who changed their understanding of the human mind from a Freudian approach to a cognitivist approach is likely to change their specific theory of mind from being similar to their theory of the steam engine to their theory of a computer.

1 Giere, like many philosophers of science, actually uses the terms *theory* and *theoretical model*, rather than framework and specific theory. I think that there are enough similarities between the two sets of concepts to warrant their interchange.

Specific Theories

Specific Theories are just that, theories which address a narrower range of phenomena under the auspices of a parent framework theory. Specific theories address similar issues to framework theories. That is, 1) ontological distinctions, 2) a causal/explanatory framework, and 3) constraints on methodology. However, specific theories focus more on the ontology and explanation than on methodological constraints and thus provide us with a way of dealing with particular types of events that framework theories can not. In Ian Hacking's (1983: Chapter 12) terms, specific theories assign values for the numerous free parameters that framework theories have. Wellman (1990: 125) describes the relationship of framework theories and specific theories this way

> In general, framework theories are said to inspire, engender, frame, and constrain specific theories that constitute, articulate, or instantiate the more global theoretical positions. This relationship allows a division of labor. By generally grounding a theoretical tradition, framework theories permit specific theories to address details. Detailed theories can therefore simply presume certain background conditions, categories, and facts without explicitly defending or testing them. These assumptions are under written by framework theories.

Thus specific theories rely heavily on the 'hidden agenda' of their parent framework theory. It is just this hidden agenda that becomes a major issue of contention between differing schools of thought, say between cognitivists and constructionists. Often the pupils of a particular school of thought will only have a vaguely thought out conception of the research tradition that they work within. Indeed they are often unaware that there are any competing schools. For instance, most adherents of the dominant North American cognitivist perspective in social psychology probably have little or no knowledge of, or interest in, competing perspectives such as sociological social psychology, ethogenics, structuralism, or post structuralism (see Parker, 1989). Social cognitive psychologists are probably more interested in following their own lines of specific inquiry, such as examining the nature of mediating variables in attributions about close relationships.

Specific theories are thus likely to be more amenable to refutation or support by empirical evidence than framework theories (see Wellman, 1990: 126) although this refutation or support rarely affects the basic assumptions that constitute the specific theory, only the specific application or instantiation of the theory. Thus, the tools and methods remain intact, only their particular use is questioned.

One important feature of the framework theory-specific theory relationship is that often a specific theory, in an effort to articulate a specific area of concern within a domain, will blatantly contradict some of the features of other specific theories framed by the same framework theory. Hacking (1983: 219) notes that

> the best way to maximize phenomena and have the simplest laws is to have the laws inconsistent with each other, each applying to this or that but none applying to all.

Similarly Holland et al. (1986) note that it is perfectly possible for a person to hold contradictory theories in mind if the theories afford some sort of benefit to their holder, the most important being economy of time and effort played off against the importance of accuracy of judgment. Holland et al. note that it is more advantageous to have a general theory that explains most of the phenomena in a domain *plus* a collection of exception rules to account for the phenomena that do not follow from the general theory, than to have a theory that explains all of the phenomena in question. They give the dramatic example that, in their environment modelling system, a changing environment with 20 properties (each one detected by a binary detector) a single layer model (that is, a theory with no exception rules) would require 1 000 000 rules to predict next states, whereas a 10 layer mental model (that is, a general theory with ten different exceptions) would require a mere 4 092 rules (see Holland et al., 1986: 66-67).

Hacking (1983: 7) notes, as Lakatos did before him, that "Every theory is born refuted". That is, most new theories cannot account for some phenomena in their domain. However, it is only when a significant number or type of exceptions pose *important* problems for the theory that a crisis will occur and a new theory will be needed. The classical theory of the motion of objects is a case in point. Newton's (relatively) simple theory can explain the motion of most objects provided they do not approach the velocity of light (a speed that most of us seldom worry about). However an account of the behaviour of objects at these high velocities becomes vastly more complicated. That is why scientists who plot the trajectories of satellites and space probes are content to use more general classical mechanics than mathematics derived from the general theory of relativity. On the other hand classical mechanics has proved to be inadequate for scientists engaged in using a cyclotron to fire protons at a target at half the speed of light (see Giere, 1988: Chapter 5).

Mental Models

Mental models are specific problem representations (Wellman, 1990). The best way to understand how mental models relate to theories is to go back to the idea of *explanation*. According to Thagard (1988: 44) we explain something by fitting a phenomenon into "a previously organized pattern or context". Put another way, explanation involves locating a schema which elaborates the meaning of an event or thing by embedding it in a deeper and broader context. For instance, we could explain why we pay for our meal before we get it at a fast food restaurant by locating our restaurant event schema and locating it within a recognized context. As Carey (1985) notes schemas and scripts do not usually provide a *causal* explanation of the situation. Such an explanation would require us to delve into the deeper theoretical aspects of the situation.

> It is explanatory mechanisms that distinguish theories from other types of conceptual structures, such as restaurant scripts. To see this, consider such questions as "Why do we pay for our food at a restaurant?" or "Why do we order food before the food comes?" The answers to these questions are not to be found within the restaurant script itself; the answer to the first lies in the domain of economics, where questions of the exchange of goods and services are explained, and the answer the second lies in the domain of physics, since it involves the directionality of time.

(Carey, 1985: 201).

I believe Carey is half right here. Contemporary philosophers note that causal explanation is not the only means of explanation for "we explain something by showing what is responsible for it or what makes it as it is." (Ruben, 1990: 233). I think Carey's ideas stem from an idea that theories and schemas are somehow separate types of knowledge structures, whereas, according to Thagard's approach, a schema is not an autonomous unit but a set of regularly associated concepts within a theoretical framework (see below for a more in-depth analysis).

Of course, a common problem with this view of explanation is that not all of the things we come across in the world fit neatly into pre-existing schemas. When we come across a novel situation that does not match any of our schemas we construct a mental model to make sense of the situation.

A mental model, then, is a tool that we use to represent our immediate environment. It represents the environment in two ways: *synchronically* and *diachronically*. It represents the environment synchronically by categorizing the basic entities that the organism perceives. The resources for this basic categorization are found within the relevant framework theory (and possibly in a specific theory as well). The mental model represents the environment diachronically by predicting how the environment will change, and comparing the predictions with the actual changes perceived. If there is a discrepancy between prediction and perception then the organism's theoretical system is invoked to produce a problem solution to explain the state of affairs. The next chapter discusses this process in more detail. Once a mental model successfully explains the situation it is 'stored' as a problem solution with all of the concepts and problem solutions that were involved in its construction, ready to be utilized again in similar future situation. Holland et al. [1986] contains an in depth examination of mental models.

2.3. WHAT IS THEORETICAL KNOWLEDGE?

2.3.1. Theoretical Knowledge and its Contrasts

Alison Gopnik (1988) claims that theoretical knowledge is to be contrasted with innate knowledge, procedural knowledge, and empirical knowledge.

Empirical knowledge

She takes empirical knowledge to be those episodes or regularities that we remember without specifically interpreting them within a theory. Wellman (1990: 6) suggests that there exists a continuum

> of the sorts of knowledge a person might possess. At one end are discrete, minimally connected facts about some set of things - for example, since I am mythologically naive, my knowledge of mythical creatures such as dragons, gryphons, and unicorns, or my (impoverished) knowledge of the vice-presidents of the United States. At the other end of the continuum might be scientific theory about some domain of phenomena. For example, consider the knowledge of astronomy possessed by an expert astronomer.

Similarly, Hacking (1983: 184) suggests that there exist observations that are relatively free of theory, such as the observation of a printed page, and there are observations that that are massively theory-loaded, such as an 'observation' of the interior rotation of the sun. I agree that there are regularities and observations that we remember and that we do not attempt to consciously explain within a theoretical framework. As I will discuss later, we only attempt to explain something when it is anomalous and important for us to do so. There are also a lot of unspoken assumptions we make when we observe things but none of these need be theoretical assumptions. However, it is unwise to suppose that our descriptions of regularities or observations are not theory (or value) guided, especially within science. We often make observations with the express purpose of 'proving' a point. It is thus dubious to suppose, as the logical positivists did, that we can calmly attend to the world without interpreting it or seeking to gain information about it. On the contrary, good scientists and attentive laypeople strive to do both.

Gopnik suggests, along with Carey (1985) and Wellman (1990), that empirical knowledge is the sort of knowledge stored in scripts or schemas. As we have seen schemas are an implicit part of theoretical knowledge. Put another way, I suggest that it is possible to elicit schema-like information (descriptions of the properties and relations that constitute a typical thing or event) from people, especially in the traditional laboratory setting where subjects are asked for minimal information often after being given little chance to reflect upon or theorize about the experiment. However, this is not conclusive evidence that human knowledge can be stored coherently in an unexplained format. Research into memory suggests that we remember *meaningful* information rather than isolated, uninterpreted details (the episodic-semantic differentiation). Following Thagard's (1988) lead I would suggest that meaningful information is information that has been *understood,* that is, located within a pre-existing pattern. Memory has often been cast as a static structure into which experiences are sorted and slotted into pigeon holes. More recent models of memory paint a picture of memory as a dynamic system where recollections arise from a spread of activation through a network of concepts, propositions, or units (Eysenck & Keane, 1990: Chapter 5).

Innate knowledge

Innate knowledge, according to Gopnik, is that knowledge that is hard wired in to our brains by processes of evolution, and is triggered by later experiences. In Chapter 4 I examine innate knowledge in some detail and conclude that it is vital to a developed conception of theoretical knowledge as it *enables* (in the sense that it focuses our perceptual and cognitive processes) us to make broad ontological distinctions, to construct basic explanations, and carry out relevant actions. Without a framework of innate knowledge theorizing would be impossible.

Procedural knowledge

Procedural knowledge is generally held to be "knowledge about how to perform various cognitive activities." rather than being declarative "knowledge about facts and things" (Anderson, 1985: 199). Gopnik (1988: 200) contrasts procedural and *theoretical* knowledge by claiming that the former exhibits an "absence of a principled relationship between cognitive structures and the experimental evidence for those structures [is] not amenable to change simply as a result of new information."

However, Mark Johnson (1991: 10) takes issue with the idea of two distinct types of knowledge, claiming that it "cannot carry the epistemic weight put on it by those who think that only 'knowing that' is knowing in the eminent or privileged mode and that it is essentially sentential and propositional." Johnson argues that all of our knowledge about the world is both procedural and declarative. His argument is intimately related to the role of innate knowledge in theorizing in that the body and its movements, which are responsible for our characteristic patterns of thinking, are also products of evolution shaped by our environment. Indeed, the evolution of our cognitive processes is, in a sense, the internalisation of our environment. In this way we can conceptualize a link between the so called internal and external worlds. These issues are examined in more detail in Chapter 4.

In summary, Gopnik's attempt to distinguish between theoretical knowledge and other types of knowledge may serve a useful heuristic purpose but the distinctions may not hold much water when it comes to examining human cognition and action as an integrated activity. All knowledge is, to some extent theory-guided, if not theory-laden. Similarly, all human knowledge involves innate (that is evolved) 'understandings' of the environment and patterns abstracted from our sensorimotor exploration of that environment.

2.3.2. Everyday Theories and Scientific Theories

We now have a broad characterization of the structure and purpose of theories. It is time to examine the question of the differences and similarities between scientist's theories and laypeople's theories.

First, and perhaps rather obviously, scientist's theories are about scientific things. That is, the content of a scientist's theory is usually something relevant to their field of study (Giere, 1988). Scientist's theories tend to be about things like electrons, molecules, DNA, sex roles, or mental images. Laypeople's theories are about things like the neighbour's relationships, the state of the family car, and the financial problems of friends. The line however becomes fuzzy: both laypeople and scientists theorize about the nation's economic woes, the effects of pollution, the likelihood of a war breaking out. So content can hardly be a deciding factor in the demarcation of everyday and scientific theories.

Lay theories are often accused of being unscientific. But such a contention requires its holder to demonstrate that scientific theories have some sort of structural difference from our everyday beliefs. However, in terms of structure, everyday theories and scientific theories are probably quite similar. Both contain concepts, rules, and problem solutions, and both are part of a web of framework theories, specific theories, and mental models. Thagard (1988: 48) notes that he does not "think that we can in general distinguish on *structural* grounds between the systems of and explanations of science and those of pseudoscience and nonscience." Even those researchers who disagree with the idea that laypeople think like scientists admit that it is the *process* of theory generation that holds the essential difference not the structure of the theoretical entities themselves (e.g. Kuhn, 1989; Morton 1980).

Some researchers suggest that scientist's theories are much more rigorous than the theories of laypeople. Royce (1978) suggests that scientific theories have a habit of progressing through ordinary language, programmatic, descriptive, and explanatory stages. Theories in the latter categories are more precise conceptually and linguistically, and more theoretically powerful than those in the former categories. This rigour arises for a number of reasons such as scientists having more time for constructing theories, a greater access to technology (books, various types of equipment that extend human perception or summarise data) and a supportive social environment (a community of experts who can supply provocative criticism and ideas). People only generate detailed theories when they are highly motivated. Scientists gain high motivation because they have chosen a career in theory construction. They are assigned tasks which involving explaining extremely complicated, and often, extremely important, puzzling phenomena. Finding a cure for AIDS would thus motivate a scientist to have a much more detailed understanding of biology than a non-scientist, not because the non-scientist is any less intelligent or less rational, but because they cannot understand the puzzling phenomena of AIDS with an undeveloped theory of biology. In sum, laypeople have the capacity to generate theories of high rigour and precision, *if they are motivated to do so.* Of course, if they *do* become so motivated they become scientists. However, there is no likelihood that they will suddenly generate theories with a distinctively 'scientific structure'.

Everyday theories may be more speculative, less rigourous, and plagued by insufferable political, religious, or social prejudices but so were many of the scientific theories of the (distant and not so distant) past. In the Renaissance thoroughly respectable thinkers held that ducks were generated by barnacles and geese by rotting logs (Hacking, 1983: 70). It seems difficult to see how theory structure could differ importantly between scientists and laypeople. Several researchers have come to a similar conclusion (e.g., Wellman, 1990; Carey, 1985; Kuhn, 1989). At this point some researchers are perfectly happy to concede that scientific theories and everyday theories are essentially the same sort of structure. Others, however, argue that laypeople and scientists use distinctly different *methods* for constructing their theories. They argue that it is this aspect of theories that comprises the difference in rationality between the scientist and the layperson (e.g., Morton, 1980; Kuhn, 1989). The issue of method is an important one. It is to this topic that I devote the next chapter.

3

Methods

As there is but one way of conveying food to the stomach, so there is but one method of supplying the mind with truth (p8).

Sophia (from ***Woman not Inferior to Man: or, a short and modest Vindication of the Natural Right of the Fair-Sex to a perfect Equality of Power, Dignity, and Esteem with the Men.)***

In the previous chapter I examined the nature of theories from the static and structural point of view of theories as receptacles for knowledge. It became apparent, however, that with a deeper appreciation supplied by a computational perspective, theories are anything but static knowledge structures. Instead theories are implicit entities, coming into their own when a spread of activation encompasses a range of concepts, problem solutions, and rules. The traditional distinctions between theory and method in philosophy, and between declarative and procedural knowledge in psychology become questionable. Rather, I believe it is preferable to focus on the dynamic, procedural aspects of theories and to view static content-based analysis as a narrow appreciation of knowing (Haig, 1989; Thagard, 1988; Johnson, 1991). With this in mind I will demonstrate how the theoretical structures outlined in Chapter 2 can be illuminatingly conceived as part of a theorizing process or method. This will involve an excursion into that vital, but neglected, area of philosophy of science concerned with the nature of scientific method. I will begin by arguing that laypeople utilize a similar method of theorizing to scientists by invoking Haig's (1987; 1989) *retroductive explanatory inferential* theory of method as a framework for the processes laypeople use in coming to know the world. I will conclude by examining the differences between scientific and lay method with reference to Deanna Kuhn's (1989) ideas about the strong restructuring of method.

3.1. DO LAYPEOPLE USE SCIENTIFIC METHODS?

This question has had a long and varied career in psychology particularly in the area of social cognition (see, e.g., Fletcher & Haig, 1989). On the whole laypeople's rationality have been evaluated unfavourably by psychologists. Humanist psychologists have suggested that people have a drive toward self actualization, or happiness; those with a psychoanalytic bent view the person as pushed about by uncontrollable internal drives and desires; the behaviourist views the layperson as determined by external contingencies; the sociobiologist emphasizes biological and genetic determinants. Harré & Secord (1972) suggest that the cognitivist tradition sees the layperson as a passive information processor and insist that a less mechanistic view of people would cast them as information seekers as well as processors. In very few cases have laypeople been credited with the rationality of the scientist - a rationality that is viewed as overcoming the numerous pushes and pulls of drives and shaping conditions. One notable exception within the North American tradition is George Kelly (1955). His personal construct theory explicitly states that normal people are rational creatures.

> man [sic] is in the business to make sense out of his world and to test the sense he has made in terms of its predictive capacity. Thus, the model man of construct theory is 'man the scientist'.
> (Bannister & Fransella, 1971: 20).

Attribution theorists such as Heider (1958), Kelley (1967), and Jones & Davis (1965) have painted a similar picture of the layperson as a 'naive scientist'. Parker (1989: Chapter 4) roundly criticises this picture because of its élitist connotations - that is, that normal people are just like scientists, only dumber. To a large extent I agree with this criticism on the grounds that the model of rationality (that is, of the ideal scientist) that is proposed and subsequently used to judge the layperson, is fundamentally flawed because of its positivist-empiricist character (see also Gigerenzer, 1990; Giere, 1988: 172-178). I believe that when we consider how scientists really function from an Evolutionary Naturalistic Realist perspective, the scientist-layperson distinction loses a lot of its edge. With this in mind I will outline a *scientific* theory of method that encompasses a more realistic type of rationality that both scientists and laypeople seem to adhere to.

3.2. RETRODUCTIVE EXPLANATORY INFERENTIALISM

Haig (1987; 1989) has outlined a holistic theory of scientific method called retroductive explanatory inferentialism (hereafter REI). This complicated sounding term is derived from the idea that scientific theories are generated through a process of *retroductive* (sometimes called *abductive*) inference. Broadly speaking retroductive inference supposes that we come to notice that a group of puzzling observations would make sense if a theory (which we have just generated) was true. For example, suppose that over the last few weeks I noticed the following puzzling conjunction of events:

1) Cars pull up outside the neighbour's house in the small hours of the morning,
2) Most of the next day I hear busy noises (filing, cutting, spray painting, sanding, and dismantling) going on in the garage,
3) Every weekend a shady looking character driving a huge covered truck appears and I hear the sound of something being loaded onto it.

Suddenly I hit upon, that is, *generate,* the theory that my neighbour is 'processing' stolen cars and selling the parts to the person with the truck. The puzzling observations fall into place. What is more, I can now use my nascent theory to predict new phenomena (my neighbour will appear startled if I turn up unannounced while she is loading the car parts onto the truck), and intervene in the situation (I can call the police).

The generation of new knowledge using retroduction is only part of the theorizing process. In addition to generation, Haig (1987; 1989) outlines a further four contexts of method. These contexts include: problem formulation and selection, data collection and analysis, theory development, and theory appraisal. This scheme is summarised diagrammatically in figure 3.1.

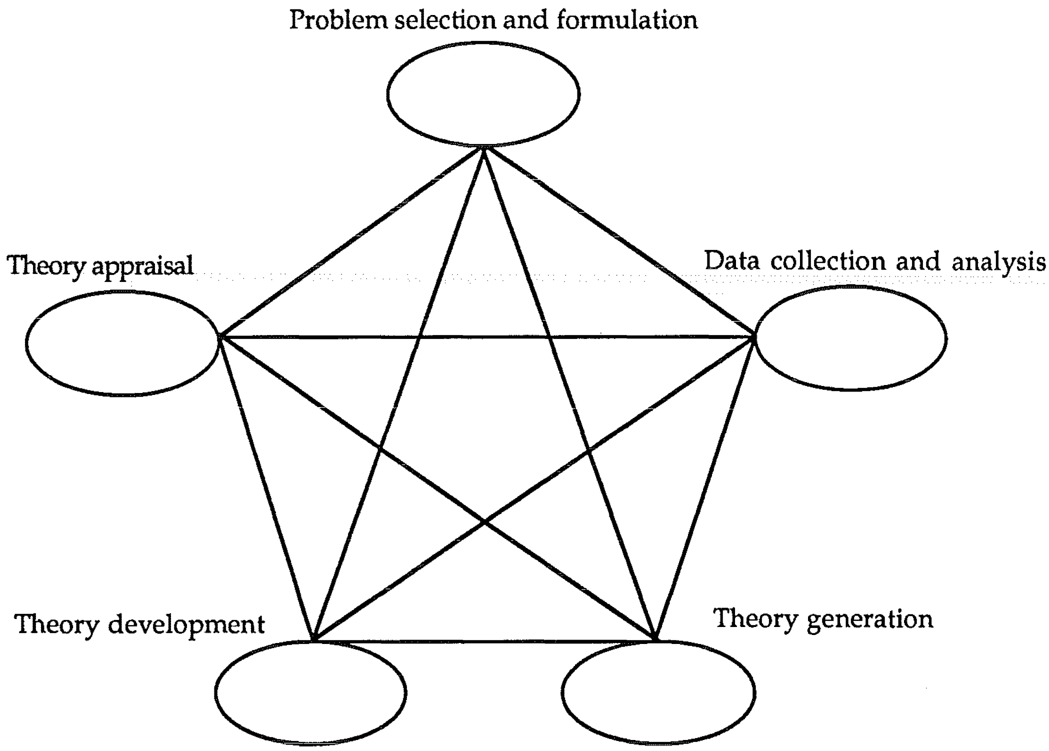

Figure 3.1
The dynamically interacting contexts of REI

The basic nature of the additional contexts can be illuminated by returning to the example of my criminal neighbour. It is likely that I will *develop* my original theory by positing, by analogy, that the situation is akin to other phenomena I am familiar with. Since I know relatively little about the underworld, I infer that the situation must have similarities with any business - there needs to be a supply of materials and thus suppliers, there needs to be customers, my neighbour must advertise the fact that she has saleable goods somehow, if business is going well she will become wealthy, if not, then not. Or perhaps the situation is more like a factory, where my neighbour is in fact a worker paid by a boss, merely passing the finished goods onto the next employee in the line, the truck driver. I have a number of plausible theories at hand. Which one is correct?

As I develop my theories I need to *appraise* them. One way of doing this is by testing my theories by experiment. I construct a hypothesis to play one theory off against the other. I hypothesize that if I watch the exchange between the driver and my neighbour and she accepts money then it is more likely that the business model is correct and the factory one is not. However, there are flaws in such a plan. It may be the case that the business model is correct but no exchange goes on. The money is exchanged elsewhere, perhaps through automatic bank payments. Or perhaps the factory model is correct and the driver is merely passing on the salary from the boss. Obviously I need to do more experimenting. No experiment can be absolutely conclusive and it may be the case that some experiments are just not possible (I could bug my neighbour's house but I do not have access to such technology). Obviously there are other criteria that can help me judge the likelihood of the truth of my theories. Which theory accounts for a larger amount of the facts? Which theory produces more accurate predictions? Which theory seems simpler and does not seem to require a whole lot of auxiliary hypotheses for it to make sense?

It is obvious that REI requires us to view the construction of theories as a complex social and cognitive task. REI is, thus, a theory of method that seems more suited to the interests of psychologists studying 'naive science' than is the rather stark logical and statistical models of reasoning advocated by empiricist philosophers of science. Most of the rest of this chapter concentrates on giving a fuller characterization of REI than that given so far. I must note at this point, however, that it is still a broad and rather skeletal conception of the theorizing process which needs to be developed by additional empirical and conceptual research.

Before exploring the contexts of method in more detail I should note that there are some caveats to the theory of REI. First, it is important to realise that these contexts are *not* stages that unfold in chronological order. Figure 3.1 shows that, in the generation and application of knowledge about the world, there exists a whole host of feedback loops and parallel endeavours. Indeed, it is important to note that scientific method is a recurring cyclic process. Second, not all incidents of science or layknowing require the theorizer to work through all of the contexts. It is important to note that this is a *theory* of scientific method and a new theory at that. All that I claim is that this is a reasonable framework in which knowing may be usefully anchored. Not all individual scientists or laypeople are in the business of generating theories. Indeed, within science it is common to have a division of labour made up of relatively autonomous groups of speculators, calculators, and experimenters (Hacking, 1983). What follows, then, is a characterization of the contexts that *can* occur in the theorizing process. It is not a step by step algorithm for making theories.

3.2.1. Problem Selection and Formulation

The whole theorizing process can be viewed as an attempt to establish the exact character of a particular problem so that a solution can be found. Such a view of problems is known as the *constraint composition* account (Nickles, 1981; Haig, 1987: 25).

> the constraint-composition model takes a problem to comprise all the constraints on the solution, plus the demand that the solution be found. On this formulation the constraints do not lie outside the problem but are constitutive of the problem itself; they characterize the problem and give it structure. The explicit demand that the solution be found arises from the goal or goals of the research programme, the pursuit of which hopefully leads to filling an outstanding gap in the problem's structure.

Thus, data collection and analysis, theory generation, development, and appraisal are all important aspects of characterizing a problem. Problem solving, then, is an extremely complicated process. In cognitive psychology problem solving research usually concentrates on the solution of well conceived problems, problems whose goals and major constraints are made obvious by the experimenter. Take, for example, the celebrated Tower of Hanoi problem (Anderson, 1985: 213-216). With this problem the environment is known to consist of three disks of increasing size (A, B, C) and three pegs (1, 2, 3). The initial conditions consist of having the disks placed one on top of the other, the smallest at the top, the largest at the bottom.

The goal state is to have the same configuration of disks on peg 3. The constraints on the solution include: 1) only the top disk of a stack can be moved, 2) only one disk can be moved at a time, 3) a moved disk must be placed on a peg, and 4) a larger disk may not be placed on a smaller disk. Obviously many of the important aspects of problem selection and formulation are supplied to the experimental participants. In this sense the problem has already been half solved by the experimenter.

Problem Selection

Problems are selected based on an organism's goals and understandings of aspects of its environment. Solutions may be necessary for a number of reasons: for survival, for the sake of curiosity, or as a designated task (as is the case for professional scientists). As noted in Chapter 2, a problem occurs when a person discovers a situation (i.e., they *represent* a situation based on the categorization provided by the relevant framework theory) which does not fit into an existing schema.

The inability to fit the perceived situation into a schema acts as a triggering condition for the activation of the problem solving process (Holland et al., 1986). This process involves constructing a mental model to construct a situation specific problem solution.

At this point a problem is typically ill conceived. The only thing that alerts a person to the fact that there is a problem is the existence of a puzzling situation that does not follow from the person's present understanding of the world. There is typically no knowledge of exactly what is amiss. For instance, take the following example of an intuitive physics problem akin to that depicted in figure 1.3 in Chapter 1.

Tom, the pilot of a small plane, has tried to drop a box of medical supplies on a marked spot on the ground. To his horror the box has sailed 20 metres past the spot and landed in a river. Tom realises there is a problem but he has absolutely no idea how it happened - whether it was due to his mistaken assumption about the motion of falling objects, or a gust of wind that caught the box, or that he accidentally hurled the box forward. The realisation of a problem is typically accompanied by an emotional reaction, which, as Jaggar (1989) notes, is a *bona fide* intentional appraisal of the situation. Tom would become anxious if he did not realise that the box of supplies he just dropped in the river were urgently needed. The emotional reaction is part and parcel of the selection and formulation of the problem, directing later problem solving.

Problem Formulation

The formulation of the problem is carried out through construction of a mental model through the processes of data collection and analysis, theory generation, development, and appraisal. This process is constrained by, what Arie Kruglanski (1989; 1990) calls *cognitive capability* and *epistemic motivations*.

Cognitive Capability

A person's understanding of the world is constrained by their *cognitive capability* in two ways: by the *availability* of knowledge (whether or not the person has a relevant schema in memory) and by the *accessibility* of knowledge (whether or not the person can activate the relevant schema at that point in time. This can be affected by the recency of activation, how regularly a certain schema is activated, and these in turn can be affected by stress or lack of time). Tom, for instance, has done engineering at university, and has a good knowledge of classical mechanics. Therefore, he has *access* to relevant information. However, he has never used these ideas out of the laboratory and does not have the relevant schema *available*[1].

Epistemic Motivations

It is absolutely essential that people have the capacity to differentiate important from non-important problems. Motivation is, in a sense, the ability to select important problems for in-depth explanation. If we were continually bombarded by situations that we felt we had to

1 Tom is not alone in making such an error. Clement (1983) notes that physics training even to university level does not mean that people will provide classical answers to motion problems. Holland et al. (1986) note that principles learnt in formal physics classes enter into competition with, rather than replace, intuitive principles. In many cases the applicability of classical principles is not immediately obvious in object motion problems, resulting in the person falling back on intuitive ideas for a solution.

solve in intricate detail it is likely we would rapidly become extinct. The reverse is also true - paying lip service to major problems would eventually result in our demise.

Kruglanski (1989) suggests that there are four basic epistemic motivations: a need for specific closure (a desire for a particular type of knowledge), a need to avoid specific closure (a desire to avoid a particular type of knowledge), a need to avoid specific closure (a desire to avoid a particular type of knowledge), and a need to avoid nonspecific closure (a desire to avoid any sort of knowledge). If someone wants an answer to a puzzle given a limited amount of time or little interest in the solution (that is, have a need for nonspecific closure) then the process of theorizing is likely to 'freeze' - that is, come to an early halt. Conversely someone who has a need to avoid nonspecific closure will be unlikely to freeze their theorizing. Those with a need to avoid specific knowledge may or may not tend to freeze-up depending on the situation (see Kruglanski, 1989: Chapter 2). As we will see in Chapter 4, a person's epistemic motivation can be greatly influenced by their position within social institutions.

These epistemic motivations can be viewed as arising out of a person's aims and goals for a particular domain of phenomena (aim-oriented, regulative principles in framework theories [q.v.]). A person who has a particular interest in a certain domain is more likely to exhibit a need to avoid nonspecific closure when dealing with phenomena from that domain. A person's motivation to select, and consequently formulate and solve problems, is also constrained by the situation; for example, how much time is available, how important it is that the solution be correct (the 'fear of invalidity problem'; see Kruglanski, 1989), and how much useful information the person can recover from the situation.

Problems are thus formulated by processes of data collection and analysis, and theory generation, development, and appraisal. The formulation of a problem typically involves the restructuring of a person's theory system through the establishment of new concepts, rules, and problem solutions.

3.2.2. Data Collection and Analysis

Theories are by their nature about things in reality and that reality finds its way into our theories via the collection and analysis of perceptual information. We are constantly collecting data from the environment when we move about it. Rarely do we passively absorb reality as empiricists would have us believe (Hooker, 1985; Jaggar, 1989; Gergen, 1979). The information that we receive through our sensorimotor window is specially selected information that picks up important facets of the environment; that is, it is information that is of interest to our survival or relevant to our goals. This information can be attended to both consciously and unconsciously through a process of *cognitive management* (Fodor, 1991). Cognitive management, according to Fodor, is the process of putting questions to nature. It occurs in many organisms as a type of reflex.

> If there are noises off, many organisms will orient reflexively to foveate the noise source ... Not because these organisms are designed to like their sensations to come in a certain order ... but because they are designed to so position themselves that if, for example, it was a Heffalump that made the noise, then they will come (and promptly too) to *believe* that it it was a Heffalump that made the noise. They achieve this by turning so that if it was a Heffalump that made the noise, then a foveated retinal image as of a Heffalump will be formed. And the reason *that* works is that, on the one hand, the world is so constructed that almost nothing but a Heffalump ever causes a retinally foveated image to be as-of-a-Heffalump; and, on the other hand, the minds of these animals are so constructed that, if an image as-of-a-Heffalump is foveated on their retinas, a Heffalump belief is thereby caused in them.
> (Fodor, 1991: 217)

Humans, in addition to this reflex, have developed a more conscious way of collecting data through cognitive *self*-management or, what is more commonly known as, *experimentation*.

> An experiment to test the hypothesis that *P* is an environment designed to have the property that *being in that environment will cause the scientist ... to believe P if (but only if) P is true.* An experiment is a sort of trick you play on yourself; an exercise in cognitive self-management ... An experiment is a gadget that's designed (not to cause you to have certain experiences but) to cause the state of your mind to correspond to the state of the world.
> (Fodor, 1991: 211).

Data collection and analysis is therefore a directed and selective activity, not a passive, global one.

Analysis

Collection and analysis are inseparable activities. We collect data by experimenting with events and entities in our environment. But data never comes to us in a 'raw' form. Rather, they are typically organized in such a way as to highlight interesting or important patterns of phenomena. Put another way, data are always analysed. Our perceptual system provides a basic analysis of environmental information, but we often analyse data more deliberately using diagrams, graphs, physical models, descriptive statistics, and other forms of external representation. This "analyzed data serves as a launching pad for the generation of new explanatory theories ... Extensive data analysis is important for theory generation because thickly described data is more likely to throw up the puzzles that prompt the introduction of new theories." (Haig, 1989: 3-4).

Experimentation

Experimentation and quasi-experimentation are typical ways of intervening in the environment to create data for collection and analysis. It is worth reiterating that data do not jump out of the environment into our heads but rather are coerced out of reality by active experimentation. Experimentation is often taken to be peculiar to science. Often psychologists point out that laypeople do not experiment scientifically because, for instance, they do not adequately differentiate theory and evidence, adjust theories to account for discrepant evidence, or isolate variables (see Kuhn, 1989; Moshman, 1979). However, as I will argue in the final section of this chapter, the conception of scientific experiments typically used in these studies rely on empiricist assumptions about the nature of scientific inquiry. Issues of randomization, operationalisation, and replicability are likewise unnecessary empiricist additions to the scientific concept of experiments (see Haig, 1991a; Greenwood, 1982; Hacking, 1983). An experiment is roughly

> a systematic, preplanned sequence of operations and observations where the following four conditions obtain:
>
> a) the system of entities under study is *relatively isolated* from the influence of certain classes of causal factors
>
> b) other factors are *held constant* or quasi-constant by the experimenter
>
> c) still other factors are *manipulated* by the experimenter, their values either being set for different individuals in the system, or changed over time at the experimenter's will
>
> d) *output* is recorded at the time.
>
> Note that this characterization of an experiment says nothing about apparatus, instruments, measurements, or even being in the laboratory. (Haig, 1991a: 1).

The degree to which variables are held constant, the nature of the manipulation and the form of output are all based on "what you know about the way that the experimental environment works" (Fodor, 1991: 211). A child who has trouble balancing two blocks on a balance beam because they do not realise that the position of the fulcrum is an important variable is not being unscientific. Rather they are not isolating the fulcrum variable *because* they do not conceive of it as an important part of how the experimental environment works (see Siegler, 1983). Scientists are just as prone to this sort of problem as laypeople are. Procedures for experimenting are thus integral parts of our framework theories. They tell us what we know about the experimental environment, what entities exist, how they interact, and how we can observe and influence them in the real world. *There is no such thing as an abstract knowledge of best experimentation.* Every domain has its own procedures for experimentation and these are based in good part on the present understanding of the phenomena in the domain. When institutions such as the American Psychological Association advocate a particular way of doing best experiments they run the risk of stultifying the scope of research. Experimental methods can only reveal interesting new data if their structure reflects insightful understandings of the phenomena they are constructed to deal with.

Data collection and analysis occur at all stages of the theorizing (problem formulation) process (Haig, 1989; 1991a). Experiments serve a number of purposes in addition to the much publicised one of discovering whether the predictions of a (specific) theory ring true. Figure 3.2 shows how data collection and analysis in the form of experimentation plays a role in different contexts of the theorizing process.

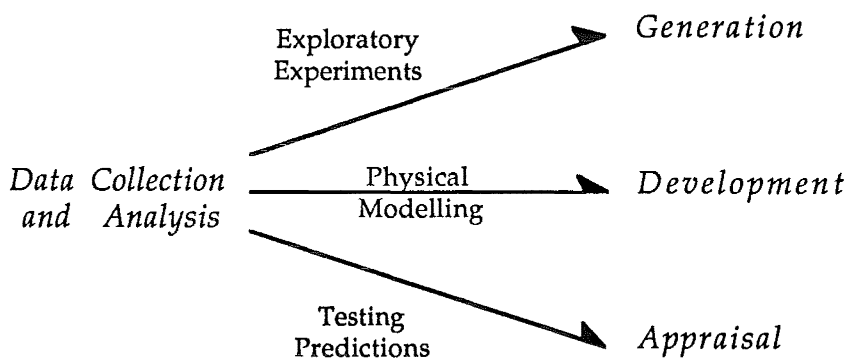

Figure 3.2
The role of experiments in the contexts of theorizing

In the context of theory generation people use experiments to simply explore a puzzling situation, somewhat like a detective carefully analyzing the scene of the crime, before any theory is generated or any causal mechanism is postulated. Such activities serve to present the theorizer with rich patterns of puzzling data which can prompt the generation of new theories (Haig, 1991a: 4). Tukey (1980) criticises psychology for its lack of concern for getting good data before launching into the creation of high brow hypotheses for testing.

Experimentation also has an important role in theory development. Haig (1991a: 4) notes that

> In the *context of theory development* we sometimes create a physical model to simulate an otherwise unsearchable process. By manipulating the model and seeing how it behaves we infer corresponding processes in the real thing. One striking early example of this was Theodoric's use of glass globes in the 13th century to simulate the causal role of raindrops in the formation of rainbows. Similarly, in social psychology it is sometimes necessary to employ "role playing" experiments in order to simulate the participant agents' representations of their situations and actions.

Experiments in the development phase can also involve careful measurements of constants and the magnitude of various phenomena (Hacking, 1983).

Finally, experiments serve a purpose in the theory appraisal context. We often conduct experiments to see if a certain phenomenon can be created based on our theory's conception of the causal structure of the phenomena of interest. Experiments in the theory appraisal phase often attempt to achieve closure of the experimental system (Greenwood, 1982). Once we can regularly create a phenomenon we are in a good position to generate a good theoretical conception of the causal entities at work. Contrary to popular (empiricist) opinion, experiments are never replicated in order to give more support for a theory or hypothesis. Rather, as Hacking (1983) notes we usually slightly alter our experimental conditions in order to ensure that we can regularly produce the desired phenomena. When we have done that we know that we have successfully isolated the system in question.

Experimentation, then, is simply a case of fiddling with the real world to create data for our theorizing. Laypeople spend a great deal of time experimenting - trying to work out how to make a new VCR work, playing around with a new computer application, constructing a fence that will stay up in loose soil, trying to make a meal taste good by substituting new ingredients, seeing if not answering back will nip those arguments with your partner in the bud.

Briefly stated, data collection and analysis is an ongoing process of interacting with reality to inform our theories. In the words of Francis Bacon (1560-1626), we must "twist the lion's tail" in order to learn anything useful from our environment (Hacking, 1983: 246).

3.2.3. Theory Generation

Given a pattern of puzzling data people use *ampliative inference* to create or modify knowledge structures such as concepts, rules, and problem solutions (Thagard, 1988). Ampliative inference is any sort of inference which causes an increase in knowledge. Roughly following Thagard (1988) I believe we differentiate two types of ampliative inference: *descriptive ampliative inference* and *explanatory ampliative inference* (Haig, 1989).

Descriptive Ampliative Inference

When people simply infer from a specific instance of a puzzling phenomenon that all or many other instances of that phenomenon will possess the same properties or result in the same events taking place, they are engaging in descriptive ampliative inference. No attempt is made to explain the underlying causes of the puzzling phenomenon. The modification of knowledge through descriptive ampliative inference does not just involve generalization, but also specialization and concept formation.

Generalization and Specialization

Generalization and specialization are complementary types of induction. Through generalization some of the conditions of a rule are dropped because they are unnecessarily specific. For instance, the rule 'IF you stroke a black cat THEN it will purr' can be generalized by dropping the 'black' condition. Conversely, a rule can be narrowed down (made more specific) by adding extra conditions. For instance, the rule 'IF X is an animal with wings THEN X can fly, would fail to predict the behaviour of a penguin, and could be modified to 'IF X is an animal with wings and is not waddling and pudgy THEN X can fly' (Holland et al., 1986: 88-97). Generalization (often called enumerative induction) has had a chequered career in philosophy and science over the centuries. Critiques by David Hume

(1711-1776) and others led people to believe that there is no form of (enumerative) induction comparable with formal deduction. Indeed the problem with constructing a formal induction was probably responsible for logical empiricists rejecting the idea of a logic of discovery. However, generalization, properly conceived "considers not just confirming instances, but also background knowledge about variability." (Thagard, 1988: 29). For instance, people realise that the property of a metal is likely to be shared by all instances of that metal, whereas a human trait, such as obesity, is likely to vary enormously amongst its members. This knowledge guides our impulses to generalize about different phenomena (Holland et al., 1986). Thus generalization and specialization are both heavily constrained by aim-oriented, metaphysical, and heuristic regulative principles embedded in our framework theories.

Concept Formation

People also generate new concepts of observable entities (for example, a new type of animal), and theoretical entities (such as black holes or electrons). An observable concept can be constructed by combining other concepts. For example, if a person had never seen a giraffe before, a new concept may be formed from concepts such as long-necked, spotted, four legged, and so on (see Thagard, 1988: 65-70). Of course new concepts would only be formed from a combination of old concepts if the thing represented by the new concept possessed properties that the combination of old concepts could not account for.

> For example, "striped apple" is a useful combination, since you expect apples to be mostly red or green rather than striped. Similarly, "feminist bank teller" is an interesting combination, since feminists are typically expected to have more professional occupations and be more politically active than bank tellers
> (Thagard, 1988: 66).

Theoretical concepts (that is, concepts of unobservables) can only be created by conceptual combination after explanatory ampliative inference has first constructed rules that relate the perceivable concepts. For instance, Thagard (1988) notes that the theoretical concept *sound wave* is constructed by combining the two *observable* concepts *sound* and *wave*. However, the only way that these two concepts become associated is through the use of retroduction to form the hypothesis that sound behaves like an observable wave. That is, given the puzzling phenomenon that sound reflects (i.e. an echo) descriptive ampliative inference would only result in the combination of the concepts *sound* and *reflect*, or generalize that since this particular sound reflects that all sounds reflect. It remains for retroduction to look for the connection of *sound* and *wave*.

Descriptive ampliative inference, although a useful enough process for acquiring networks of concepts and laws, has a major failing in that it does not attempt to explain the nature of the puzzling phenomenon in a way that is useful for decisive intervention in the environment. Because of this limitation, explanatory ampliative inference (that is, retroduction) is a vitally important to the survival of the organism utilizing it.

Explanatory Ampliative Inference

Rather than simply combining or modifying knowledge as generalization and concept formation do, retroduction uses background knowledge to explain rather than describe a pattern of data. As the name suggests retroduction is the process of reasoning back to (underlying) causes of some puzzling phenomenon.

Types of Retroduction

Retroduction can be seen as varying along two dimensions: a *specificity* dimension and a *explanatory depth* dimension (see Table 3.1).

In terms of specificity, a retroduction can be carried out in order to explain a specific event or to apply to a broader class of events. For example, Tom the pilot may only want to work out why the medical supplies did not land on the correct place in this particular occasion. He may not be overly concerned with the physics of the problem and may merely want to find some sort of simple remedy for the problem. If he was particularly interested in this phenomenon (perhaps a similar thing has happened before) he may want to find a more general explanation for the puzzling turn of events.

The explanatory depth of the retroduction is a reflection of how 'deep' a solution the theorizer is looking for to explain their puzzling phenomenon. The theorizer may simply want to fit the puzzling phenomenon into some sort of vaguely recognisable context or they may want to posit the causal powers and structure of the underlying mechanism at work. The epistemic motivation to explain a phenomenon (Kruglanski, 1989; 1990) is thus an important constraint on the type of retroduction that takes place. A person with a desire to avoid nonspecific closure is more likely to opt for an analogical general retroduction, whereas a person with a desire for nonspecific closure will want to perform a quick simple specific retroduction.

Table 3.1
A taxonomy of types of retroduction

	specific	**general**
simple	simple specific retroduction	simple general retroduction
existential	existential specific retroduction	existential general retroduction
analogical	analogical specific retroduction	analogical general retroduction

Simple Retroduction
Simple retroduction occurs when we come across a situation and we make one or more hypotheses as to their explanation based on knowledge that we have. For instance, Tom wants to explain why 'an object dropped from a height did not fall straight down'. Tom also knows that 'an object thrown forward does not drop straight down', so, through simple retroduction, he hypothesizes that he threw the box forward.

Existential Retroduction

Existential retroduction involves positing the existence of unobserved entity as the cause behind the puzzling phenomena. For instance, British astronomers posited the existence of a distant tenth planet (Planet X) because they were faced by the puzzling phenomenon of the unusual orbits of a group of fifteen comets (The Press, 1991).

Analogical Retroduction

Analogical retroduction is the most complex and time consuming type of retroduction. An analogical retroduction uses an analagous problem solution as the speculative explanatory framework for a puzzling phenomenon. Thagard (1988: 61) gives the following example:

> Suppose you are trying to solve a crime involving the murder of a rich woman. You may be reminded of another case in which a rich woman was murdered, and in which the hypothesis that she was murdered by her philandering husband turned out to be true. Because of the similarity of the cases, you may form the hypothesis in the new case that a philandering husband was responsible. Such a hypothesis will be flimsy in the absence of further evidence, but may be invaluable in suggesting what evidence to gather. The form of reasoning here is, Hypothesis H was the right explanation in case C_1 that is like the current case C_2 in many respects, so an analog of H might work in C_2.

Generally, the deeper the explanation we seek, the more general its application would be. This is, perhaps, one of the central objectives of modern science. However, it is possible to imagine someone constructing an elaborate analogical retroduction for a specific problem, perhaps to impress or convince someone of something. Politicians, no doubt, have developed this skill to a fine art!

Constraints on Retroduction

Retroductive inference is constrained by regulative principles some of which are the deep ontological commitments of our broad framework theories. So we only entertain candidate theories that encompass our basic beliefs about the world. Of course, although framework theories are extremely robust they are not inviolate, and these regulative principles can themselves be overlooked, given adequate reasons (most likely the possibility of a different (partial) world view in the form of an alternative framework theory [Hooker, 1975]).

The key to useful theory generation is to embrace a thorough-going pluralism (Haig, 1989). Pluralism works best in a scientific or lay community where different individuals or groups contribute and criticise different theories. But the individual can also increase chances of attaining the best theory by remaining open minded (having a need to avoid nonspecific closure) and entertaining the possibility of a number of candidate theories (see Kruglanski, 1989; 1990; Giere, 1988).

3.2.4. Theory Development

Theory generation leaves us with a number of seriously undeveloped explanations for our puzzling phenomena. It sets up some speculative connections among existing knowledge structures. New concepts are introduced by conceptual combination, existing concepts are modified by generalization and specialization, speculative rules bind previously unconnected problem solutions and concepts together. The context of theory development is one that attempts to exploit these early 'educated guesses' by following through the implications of the new speculative relationships, modifying them, and using them as the basis for making novel predictions about the puzzling situation. This process is aimed at "the mathematical alteration of a given speculation, so that one brings it into closer resonance with nature" (Hacking, 1983: 214). Theory development involves tying a theory down to make it more practical and usable. The process is *mathematical* because it refers to a conceptual tightening that reveals some relatively specific and practical procedure for explaining and predicting real-life phenomena rather than the *ideal* phenomena hinted at in the speculative phase of theory generation.

The Use of Iconic Paramorph Models

Theory development standardly requires us to detail the nature of the theoretical (nonobservable) causal concepts at the heart of our theories. This standardly involves reasoning that the causal entities are analagous to other structures already known to exist. Put another way, we import an existing problem solution from elsewhere in our knowledge store, because it involves similar concepts and/or rules, and insert it as the basic causal process underlying the puzzling phenomena.[2]

Often the *models*[3] we use to do this are (superficially) quite different from the puzzling phenomena we are dealing with. They are regularly imported from knowledge of different domains. This sort of model is said to be a *paramorph* (Harré & Secord, 1972). For instance, William Harvey (1578-1657) based his understanding of the circulation of blood on the model of a hydraulic pump. In a similar way, much of modern psychology uses the metaphor of the human mind as a computer. In both cases we use technological models to inform puzzling biological phenomena. Laypeople often utilize models in their theories about the world. This is sometimes revealed in our metaphorical talk. For instance, we might talk about someone as having 'a mind like a sieve' or 'being blocked on their pathway to success'. Although these statements often seem merely colourful and theoretically useless they can actually give us important insights into our theoretical concepts of a phenomenon (Johnson, 1991). For instance, if we think someone has a mind like a sieve we typically blame their mental faculties for any problems that occur with regards to their memory. It is likely that we would use a different metaphor if we thought that, say, situational factors, such as having a busy week, were thought responsible. In this case we may think that their 'mind is crowded by stressful thoughts'.

---

[2]The use of analagous models in theory development may be confused with *analogical retroduction* in theory generation. Analogical retroduction typically uses superficially similar problem solutions as the basis for making a speculation of the general shape that the theory should take. In contrast, analogous models in theory development are utilized to detail the underlying causal variables and thus the source model often comes from a different domain to that being considered in the theory under construction.

[3] In this work I use the terms *model, iconic paramorph,* and *(imagistic) problem solution* interchangeably. *Mental models* are related to these entities but are not exactly the same. Mental models are entities which give rise to the construction of problem solutions (see Chapter 2).

In addition to the model coming from a source domain different from the domain of the developing theory, these models are usually visual or, more generally, imagistic. That is, they provide us with a macroscopic model of an unobservable entity. Many cognitive scientists hold that it is important that our models are imagistic rather than mathematically abstract (Hacking, 1983; Giere, 1988; Johnson, 1991). The process of utilizing our sensorimotor experience to inform our understanding of things we cannot perceive is argued to be a vital and natural process of human cognition. This idea will be examined in more detail in Chapter 4. Thus, Harré and Secord (1972) call these imagistic problem solutions that are imported from different domains *iconic paramorphs*.

Thagard (1988: 22-27) gives a simple example of the use of an analagous problem solution to solve a puzzling phenomenon. The problem consists of inventing a way to destroy a tumour in a person's stomach using a special ray, without also destroying healthy tissue (this problem is taken from, Duncker, 1945). In an experiment by Gick and Holyoak (1980), this problem was found to more easily solved when participants were supplied with a model of an analagous situation. This situation involved an army storming a fortress on four fronts because an insufficient number of soldiers could attack from a single front. Thagard suggests this process can be simulated computationally in the following manner:

1) The model problem solution is retrieved through the spread of activation through a series of concepts. The puzzled person formulates the problem to include concepts of *ray, destroy, tumour,* and so on. Through the directed spread of activation laterally (by association of concepts) and hierarchically, the system also activates other concepts (*ray* activates *shoot, bullets, guns, weapons, fight, army,* and so on; *destroy* activates *defeat, conquer, capture*). This process results in the retrieval of problem solutions linked to these concepts, including the solution to the fortress problem.

2) The analagous model is then exploited to aid in the explanation of the puzzling phenomena. Analagous concepts are mapped onto

each other (e.g. *ray* to *army, tumour* to *fortress*) and an analogical procedure for explaining the phenomena is found (in this case the concept *split-up*).

3) As noted in Chapter 2, the use of a certain 'high level' procedure for explaining or solving a problem results in the abstraction of a more general problem schema for further use in later problem solving. In this case the problem schema would look something like that depicted in figure 3.3.

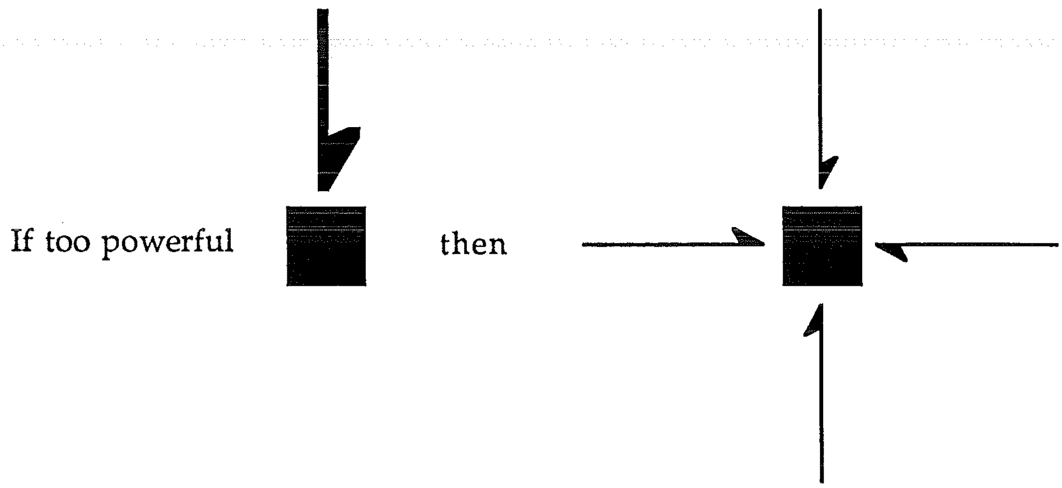

Figure 3.3
The abstracted problem schema from the *Capture Fortress* and *Destroy Tumour* problem solutions.

This example is, of course, quite simplistic compared to the use of analogy in science and everyday thinking. An iconic paramorph would *not* typically map so neatly onto the puzzling phenomena. A person would have to deal with a significant number of *disanalogies.* The iconic paramorph is likely only to provide a very rough explanation of the causal structures at work. Initially the model merely stands in for the hidden entity, but as it becomes apparent how the analogy succeeds, and how it fails, we develop a more precise and rigourous understanding of our theories' theoretical entities and they take on a independent character often far removed from the source model. In physics this is most obvious in the particle and wave models of the subatomic world. Hooker (1975) notes that these two approaches have permeated Western metaphysics since the Greek philosophers. Each is based on the concept of a macroscopic (observable) phenomenon but both have evolved to a point where the phenomenon that physicists regularly refer to as particles or waves are really nothing like ball bearings or ripples in a pond.

Theory development, then, involves tightening and clarifying of the speculative ideas that come about through theory generation.

3.2.5. Theory Appraisal

In the processes of theory generation and development regulative principles provide constraints on the structure and content of the theories we create. However, these principles do not ensure that *everything* generated and developed will be useful or even sensible. In order to ensure that our theories make good sense, that is, are reasonably accurate representations of the phenomena they depict, we need to appraise our theorizing efforts (Thagard, 1988: Chapter 5).

Inference to the Best Explanation

The evaluation of our theoretical ideas occurs at all stages of the theorizing process (see figure 3.4). We need to appraise, not only our highly developed theories, but also our speculative candidate theories. Thus, theories at different stages of development must be evaluated in different ways. For instance, only developed theories can be expected to fit the data in a reasonably precise way.

A theory is never evaluated without reference to competing theories (Haig, 1989; Thagard, 1988). The process of evaluating a theory is done through *inference to the best explanation* (Thagard, 1988; Musgrave, 1988). Inference to the best explanation involves finding the *best* theory of those available to explain a certain group of puzzling phenomena. It can be regarded as a sensible survival strategy because it holds that it is better to have a vague, slightly useful explanation of a state of affairs than to have no explanation at all.

The major problem with using inference to the best explanation as a usable concept is characterising what we mean by *best*. In order for our theory system to assess the quality of a theory it needs to possess some evaluative regulative principles. These principles are sometimes called *epistemic values* (McMullin, 1983; Howard, 1985) because they are statements of what we take to be good indicators of satisfactory knowledge.

Epistemic Values

Our theory system defines what we take to be valuable knowledge. In particular, the type of epistemic values we give priority to are influenced by our goals and aims. Fletcher and Haig (1989) list four typical scientific aims: truth, understanding, prediction, and control.

Typically laypeople and scientists have a number of goals in mind when they generate theories. On balance, however, people seem to want to know the real nature of a phenomenon because such knowledge provides us with the ability to usefully intervene in the situation. The goals of prediction and control give us very little chance to effectively change a situation. Prediction alerts us to what the future may hold and we can thus plan to take advantage of such a situation, but it leaves us at the mercy of the phenomena in question. Control enables us to enforce our desires on a situation but it does nothing to utilize or alter the structure of a problem except, often, to aggrevate it in the long term.

Different epistemic values will no doubt manifest themselves in scientists who emphasize truth compared to those that emphasize control. For instance, Parker (1989) notes that a great deal of social psychological research, Soviet as well as North American, has (and probably still does have) an image of collective behaviour and cognition as unruly, biased, and out of control. He suggests that the emphasis on individualism in social psychology goes a long way to substantiating oppressive control of the underclasses. So the aim of control, in this case, leads us to favourably evaluate theories that encompass an individualistic approach.

Thus, our epistemic values derive from the view we hold of our role in the world. Empiricists hold that science is, or should be, as objective as possible. They believe that there is only one valid epistemic value, that of *empirical adequacy*. A theory is empirically adequate when independent evidence verifies the predictions of the theory. There are two major problems with assuming that empirical adequacy is the only valid epistemic value. First, theories themselves rarely furnish us with hypotheses that can be tested that can prove or refute the theory (Hacking, 1983). Second, newly generated theories are often so rough that their connection with real phenomena is, to say the least, tenuous. This, however, does not mean that the theory is completely wrong. In fact a theory can be plausible and show a great deal of potential even when it does not seem to be useful or accurate at first blush. Take, for example, connectionist architecture. Its early forms were roundly criticised by Minsky and Papert (see Pollack, 1989) and quickly went into hibernation. Recently the connectionist ideas have come back with a vengeance, the earlier problems vanquished by new conceptualizations of the paradigm.

These problems suggest that theory appraisal needs to be based on other conceptual criteria as well as empirical adequacy (Thagard, 1988; Kuhn, 1970). Haig (1989; 1991c) suggests the following important conceptual criteria.

Existential Depth
Good theories have a detailed conception of the underlying causal structure of the relevant phenomena such as subatomic particles or social stratification.

Explanatory Power
The ability of a theory to account for a large number of facts constitutes its explanatory power (Thagard, 1988). Theories do this best when an underlying structure or process is postulated which explains facts as instances or effects stemming from the basic causal powers.

Initial Plausibility
This epistemic value involves checking to see whether our speculative candidate theories are the result of sound retroductive reasoning. Initial plausibility, then, is a check on the effectiveness of the regulative principles used in theory generation.

Fertility
A good candidate theory has the potential to link disparate knowledge by reconceptualizing some basic concepts or by hypothesizing rules that link concepts in interesting new ways. A theory that postulates a new basic conceptualization of the world is likely to be very fertile because it will have far reaching effects on the conceptualization of many concepts, rules, and problem solutions.

Systemic Worth
A developed theory that coheres with other theories and does not have obvious internal consistencies is said to have high systemic worth. Systemic worth encompasses the important idea of *simplicity*, the idea that we should prefer a theory that explains a number of facts using a lesser number of auxiliary hypotheses than competing theories (Thagard, 1988: Chapter 5). An auxiliary hypothesis is an extra statement that is required for a theory to adequately explain a particular phenomenon. A theory with a large number of auxiliary hypotheses, or exceptions, introduces a burden to the theory-user by requiring them to expend extra time and resources to deal with 'special exceptions'.

Guide to Action
Theories, especially developed theories, should prove to have important practical consequences for the individual or institution that created them. Theories are entities for promoting survival and thus cannot be viewed as containers for 'pure knowledge'. *In the end* all theories should be evaluated on the importance or potential importance of their practical usefulness.

Levels of Development and Types of Epistemic Value
Thagard (1988: 187) notes that "New theories, like children, cannot be subjected to the standards of grown-ups." Theories need to be

evaluated according to their stage of development. This is done through emphasising different epistemic values according to the maturity of the theory. For instance, young theories are unlikely to be evaluated mainly on criteria of *guidance to action* and *empirical adequacy* but it is likely that values such as *fertility* and *initial plausibility* will be paramount. Figure 3.4 gives a pictorial representation of these ideas.

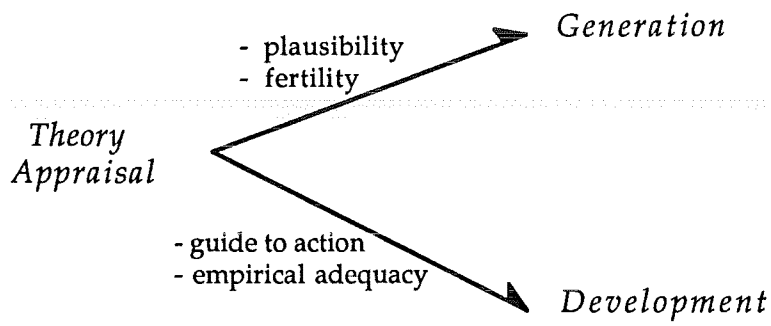

Figure 3.4
Examples of the type of epistemic values relevant to different levels of theory development.

The 'weighting' of the epistemic values at each stage of theory development is itself a dynamic process. Through our experiences in utilizing theories in practical situations we learn to value certain structural features of our theories. As noted earlier, this means that our goals and aims play an important role in the type of theory we evaluate to be of high quality. In turn our epistemic values can influence our other regulative principles. Principles and techniques that aid in generating high quality theories will be utilized more frequently. Those principles that are not deemed helpful in the construction of good theories will be gradually phased out.

Theory appraisal is a phase concerned with monitoring the usefulness and accuracy of our concepts, rules, and problem solutions. It both influences and is influenced by an individual's goals, aims, and interactions with the environment.

3.3. SCIENTIFIC METHODS VERSUS LAY METHODS

The point of this chapter has been to suggest that REI is a method that describes the theorizing processes of both scientists and laypeople. This does not mean that scientists and laypeople do the same sorts of things with their theories. They do not. Very few laypeople have generated theories as monumental as classical mechanics or Marxist sociology. These endeavours require time, resources, application, and motivation. Rather, this chapter explains theorizing as a natural human ability as opposed to some sort of esoteric intellectual feat. In philosophy of science parlance, I am advocating a naturalized epistemology rather than a rationalized epistemology (Giere, 1988: Chapter 1).

Not all psychologists agree with these sentiments. Deanna Kuhn (1989), for instance, believes that the metaphor of the layperson as an intuitive scientist breaks down when we analyze the *methods* expert scientists use compared to those of laypeople. Similarly Morton (1980: 29) notes

> Theory is risky. It depends on a delicate balance of conjecture and fact, imagination and prudence ... Free imaginative hypotheses are allowable in science just because they take place within a network of tests, observations, and opportunities for critical reflection that ensure public criticism of hypotheses and give refuting considerations a chance to appear.

However, often these sort of objections are based squarely upon an empiricist philosophy of science. Thus it is not surprising that these researchers find it easy to demarcate scientific and lay methods of generating theories. I will demonstrate what I mean by analyzing Kuhn's (1989) research in more detail.

Kuhn critiques two areas of research: the child as scientist programme pioneered by Carey (1985), Gopnik (1990), Karmiloff-Smith (1988) and others, and the layperson as scientist programme. I shall pay attention only to the latter, although what I have to say is relevant to the child as scientist tradition.

Kuhn (1989) believes that there exists a developmental continuum of the methods used by novices and experts. Novices, she says, do not differentiate between a theory and evidence.

> When theory and evidence are compatible, the two are melded into a single representation of "the way things are." When they are discrepant, subjects exhibit strategies for maintaining their alignment - either adjusting the theory, typically without acknowledging having done so, or "adjusting" the evidence by ignoring it or attending to it in a selective, distorting manner (Kuhn, 1989: 687).

Experts, on the other hand, can fully differentiate theory and evidence and do not just use theories, but are consciously aware of them.

These ideas share much with the hypothetico-deductive (HD) theory of method. Firstly, following HD method, she considers theory and evidence to be relatively autonomous aspects of method. However, following Thomas Kuhn (1970) and other researchers, I have noted that all evidence (or data or observations) is to some extent theory-laden or theory-guided (see Boyd, 1984 and Hacking, 1983 for more detailed analysis of these issues). Even Deanna Kuhn (1989: 687) speculates that novices will not utilize or understand contrary evidence unless they can appreciate an alternative theory that accounts for it.

Secondly, Kuhn hints that an instance of contrary evidence should cause strong concern for the validity of one's theory despite the fact that philosophers, such as Popper (1959) and Lakatos (1970), have shown that empirical evidence, in and of itself, can neither verify nor falsify a hypothesis.

Kuhn's studies rely heavily on these assumptions. A typical experiment in her research consists of providing a group of participants with a topic that they probably have formed a theory about (such as the cause of prisoners returning to crime or the cause of unemployment), eliciting their causal theory, asking them to provide evidence for it, to present an alternative theory that others may hold, and thinking of evidence that they may use to substantiate a contrary theory. Kuhn found that people with a low level of education (novices) would typically not be able to produce many alternative theories or generate much evidence for these theories. Kuhn took these verbal reports as evidence that novices were not theorizing in a scientific way. It is possible, however, that the studies were actually measuring people's ability to use the hypothetico-deductive method.

In order for a person to think scientifically Kuhn required them to suppose that contrary evidence discredited their theory and that supporting evidence confirmed it. However, this rarely holds in the real world. Contrary evidence does not cause us to cast out our theories as hopelessly inaccurate and supporting evidence is rarely an indication that our theory is correct. Only in a closed logical world can one instance of evidence provide a conclusive demonstration of the validity of a statement. This sort of ideal logical thinking has to be learned and many scientists and philosophers are familiar with it. Notably the 'experts' in some of Kuhn's experiments were PhD candidates in philosophy. Unlike hypothetico-deductivism, retroductive explanatory inferentialism does not require us to use formal deduction which has been shown to be quite elusive for most people (Wason, 1977). It is possible to conclude, then, that Kuhn's (1989) studies were attempting to measure participant's skills in logic rather than theorizing.

3.3.1. Experts and Novices

I think a better place to start looking for differences between laypeople and scientists with regards to method is in the field of expertise research. I think that if we cast the layperson as a novice and the scientist as an expert in a certain domain we gain more insight into the scientist-layperson relationship than we do by positing a series of developmental stages of rationality. The difference between the two approaches is one of *level of analysis*. The developmental approach of Kuhn (1989) sees the difference in theorizing methods as a case of strong restructuring. That is, scientists have a different basic method of reasoning *in all domains* in comparison to laypeople. The expertise approach however permits us to say that retroductive explanatory inferentialism (or an equivalent basic method) is common to all people. Differences in specific strategies of experimentation or reasoning are due to a person's theoretical conceptualization of a specific domain. That is, it is the specific content not a developmental process that causes differences in domain specific procedures and strategies (Kruglanski, 1989). Wason and Johnson-Laird's (1972) studies into laypeople's ability to apply the logical process of *modus tollens* show this sort of pattern[4]. They found that laypeople often could not correctly utilize this process but that in certain situations where the content of the problem involved the catching of cheats laypeople used it with proficiency. This approach, then, allows for scientists to be theoretical 'no hopers' in domains that they are totally unfamiliar with.

According to this approach an expert knows more about a given field than a novice. Because of the familiarity an expert has with their field many of the skills learnt have become complex conceptual composites and are unconscious, automatic and often quite rapid. (Anderson, 1985; Biggs & Telfer, 1987)

It appears that experts detect special types of patterns specific to their field that a novice would not. For instance, expert chess players can memorise many more positions of pieces on a board than novices because of the meaningful patterns in which the pieces are arranged. However, in a situation where the pieces are arranged on the board in a pattern that could not occur in the course of a game, the experts and novices remember about the same number of piece positions (Chase & Simon, 1973).

Experts on the whole spend more time formulating a problem than novices do. (Anderson, 1985; Sternberg 1985). It seems that the vital

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[4] Modus tollens is a rule of inference that states that "if we are given the proposition A *implies* B and the fact that *B* is false, then we can infer that *A* is false." (Anderson, 1985: 264). For instance, if we know that *if the switch is pushed then the light will come on* and we are told that the light has not come on, then we must deduce that the switch has *not* been pushed.

part of attacking a problem is getting a clear representation of what the problem actually involves. Novices however often spend little time on this initial appreciation of the whole and try to deal with the most obvious features. Such a reliance on surface data is an inefficient way of solving problems which nearly always involve hidden conceptual cores which only have tenuous ties to surface features.

All of these differences come about through familiarity with the subject matter. Experts are people who have constructed elaborate theories of certain domains by virtue of interest in their field, access to technology and a supportive social environment. By virtue of their extended knowledge they construct at first tentative theories and procedures from patterns in that knowledge. Once these theories and strategies become second nature these too can be linked together with further strategies. Soon the expert's understanding of the field leaves the surface level of the observable, that a novice would perceive, and moves to the realm of the unobservable. (Biggs & Telfer, 1987). Because it is only access to knowledge that differentiates experts and novices, and because access to knowledge is dependent on social factors we can say expertise is at least partly a social product. This means that in order to understand the scientist-layperson relationship properly we need to examine the social, political, and institutional aspects of human knowing discussed by many social psychologists and sociologists. It is to these ideas that I turn in the next chapter.

4

The Wider Picture

The ideas of the ruling class are, in every age, the ruling ideas: i.e., the class which is the dominant material force in society is at the same time the dominant intellectual force. The class which has the means of material production at its disposal, has control at the same time over the mental means of production. (p 78).

Karl Marx (from Selected Writings in Sociology and Social Philosophy).

In my brief description of Evolutionary Naturalistic Realism (ENR) in Chapter 1, I mentioned that this philosophy of science takes evolutionary and institutional factors to be vital in the theorizing process. In this chapter I hope to unpack these ideas in some detail.

4.1. KNOWLEDGE IN THE WIDER CONTEXT

I find it useful to imagine the makeup of an individual's theorizing process as an upside down triangle divided (somewhat artificially) into three parts of unequal size (see figure 4.1). The area of each part gives a rough indication of how much of the knowledge is shared among people, so that the most general sort of knowledge (that we acquire through our evolutionary endowment) is shared by all people, and the knowledge that we generate through our own private ideas and methods is specific to the individual.

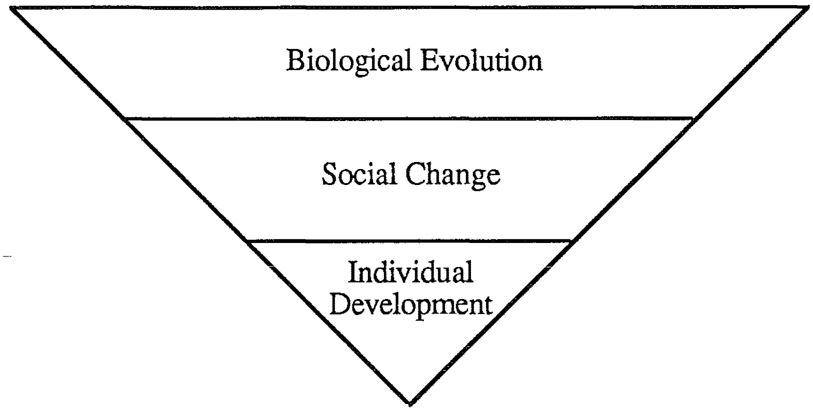

Figure 4.1
The three major contexts of knowledge

4.1.1. Biology, Society and the Individual

Biological Evolution
The top part of the inverted triangle concerns our evolved capacities for theorizing. David-Hillel Ruben (1977) calls the evolutionary contribution to our theories the *biological transmit*. It can be characterized in the following way:

1) It is insensitive to local (that is, close in space and time) environmental conditions, as it changes gradually by natural selection over thousands of years.

2) It provides a foundation to knowledge that is common to all members of a particular biological taxon (species, phyla, class, or family). Thus, for example, all healthy members of the species *homo sapiens sapiens* have the same fundamental biological capacities for knowing.

3) The biological transmit provides us with a very rough guide for theorizing about (and thereby acting on) our environment. This process seems to occur in two forms: the first provides us with a selection of innate specific theories, or Darwinian algorithms, for dealing with biologically important aspects of the environment (Cosmides & Tooby, 1987); the second provides us with the basic

system operating principles (Holland et al., 1986: 41) for generating individual theories (Shepard, 1984; 1987; Johnson, 1991). These two forms of evolutionary knowledge make up, what I call, a *species programme*. By itself this species programme provides us with a minimal understanding of reality, serving mainly to isolate and conceptualize the most basic aspects of our environment and providing us with some fundamental procedures for survival (Ruben, 1977: 110). A more detailed discussion of these ideas occurs later in this chapter.

Social Change

The middle part of figure 4.1 depicts that knowledge and understanding of reality that we have acquired via, what Ruben (1977) calls, a *social transmit*. An obvious example of knowledge derived from our socio-cultural environment would be our capacity to understand and utilize our culture's language. The social transmit can be characterized as follows:

1) It is more sensitive than biological knowledge to a changing environment. Cultures and societies adapt to a changing environment (that is, they acquire new forms for dealing with new and probably dangerous phenomena) more quickly than the slow genotypic and phenotypic changes that occur through genetic natural selection (see Dupré, 1987b).

2) Social knowledge provides us with an essential foundation for theorizing about the world. If humans had to rely on their own individual efforts to understand the world, there would be almost no progress in thinking, activity, or technology. In a sense, the wheel would have to be reinvented with the development of every generation. Society embodies the ideas of many people in the previous centuries. Our language and the shape and structure of other institutions and technologies ensure that what has gone before is seldom totally lost. Through education, indoctrination, and the passing on of oral and written knowledge, we acquire in days, weeks, and years what took thousands of years of thinking to achieve. Certainly much of what was thought in the past is lost or coloured by our present conceptions of reality, but our present social

structures serve to embody and retain a vast amount of theoretical knowledge. The importance of the social transmit is such that philosopher of *biology* John Dupré (1987b: 329) argues "that cultural variation, very probably the product of divergent cultural evolution, should be seen as the primary focus for the explanation of human behavior."

3) Although knowledge acquired through the social transmit is an integral and vital aspect of our individual theories about the world, no person "is *bound* to it, for [they] can come to critically reflect on anything which [they are] taught. That is, [they] can come to critically reflect, *if* the transmission mechanism has operated on [them] by respecting [them] as a rational agent, for people who are brainwashed, indoctrinated, etc., often are not *capable* of coming to critical reflection." (Ruben, 1977: 110). That is, although much of what we learn socially and culturally can be used to survive in a relatively static social environment, our ability to adapt and prosper in a rapidly changing environment is largely reliant on our own individual theorizing abilities.

A important feature of social knowledge is that it is common to a *group* (culture, society, institution, community, family, dyad, etc.) of individuals. It thus provides a basis for communication of ideas and cooperative action. If everybody had extremely individual conceptions of the world we would expend enormous amounts of important time and resources just trying to understand each other. We can begin to appreciate this problem when we examine the significant problems associated with cross-cultural communication. Cultures obviously place different values on different aspects of reality and even divide the world up in significantly different ways.

Individual Development

The bottom part of figure 4.1 refers to this knowledge that we acquire through our own critical, individual reflection about the world. This level is concerned with the processes and structures discussed in Chapters 2 and 3.

Individual knowledge is extremely sensitive to changes in the local environment. This ability to keep updating our conceptions and explanations of the changing local environment ensures our continued survival. Social and biological knowledge may be particularly well-suited to surviving in a relatively static environment but total reliance on them would prove fatal should the environment alter. The extinction of many animal species, especially with the increasing expansion of humans and their artifacts, is a case in point. Many of the birds endemic to New Zealand have become extinct or threatened with the introduction of mammals from other ecosystems and the widespread deforestation and hunting caused by humans. The relative slowness of social change has also resulted in the extinction of many cultures. Rome, for instance, could not adapt to the pressures of the various Germanic and Slavic tribes. Its previously successful policies of slavery and conquest eventually proved unwieldy in the changing social climate, and thus the social system that embodied these values collapsed. An over-reliance on social or biological 'conceptions of reality' exacts a high fitness cost on the individual in rapidly changing environments.

When individuals have the capacity to reevaluate the state of the local environment and use this as a basis for action, they are more likely to deal effectively with that environment. In a sense all individuals live within different environments. Only their specific conceptions of reality are likely to provide a reliable way of dealing with that environment. This does not mean that individual knowledge is always successful in adapting the individual to their environment. It is certainly the case that people suffer from psychological problems of various levels of seriousness in their lives because of an inability to adapt to their local environment. However, I believe that a significant number of these problems stem from an over reliance (whether by force of circumstance or otherwise) on social (and to a lesser extent biological) knowledge. Crime, unemployment, suburban neurosis, stress related diseases, poverty, and so on, may all result in significant 'survival problems' for the individual, but they are all cases of a *forced* over-reliance on the social transmit.

These three broad levels of knowing continually interact when we theorize about the world. It is important to realise that no level is more important than any other level. All are necessary. The upper levels provide constraints that focus the direction of the lower, more specific levels. At the same time the lower levels can override the impulses of the more entrenched and inflexible upper levels. The picture that evolves is that theorizing is a process that has been millions of years in the making, relying on natural selection and social change, as much as on an individual's cognitive development.

4.1.2. Vehicles for Knowledge

So far this broad characterization has said nothing about *how* biology and society can influence our theorizing. Intuitively we assume that theorizing goes on in our brains, the product of neuronal firings and so on, but it difficult to see how something as amorphous and vague as a *society* can 'make us think things'. Similarly, it seems odd that we can have *innate* knowledge of the way the world is. We certainly do not *feel* as if we instinctively know things about reality. How can it be that a collection of proteins can be passed on from generation to generation containing the knowledge that, for instance, "for any two positions of an object in three-dimensional space, there exists a unique axis in space such that the object can be carried from one position to the other by a combination of a translation along the axis together with a rotation about it"? (Shepard, 1987: 263).

I think the best place to start to clarify these ideas is with 1) the, now familiar, triad of ontology, explanatory framework, and methodology, and 2) by roughly characterizing the social and biological 'vehicles' of these aspects of knowledge.

As we have seen, a theory can be usefully characterized as an entity comprising three components: a collection of concepts (ontology), a description of the ways the concepts are related (an explanatory framework), and a description of the ways a person can deal with the real life phenomena that the concepts are meant to express (a set of methodological constraints). I believe that an *institution* is the appropriate vehicle for conveying these ideas socially, and a *species programme* can fulfil the role for evolved knowledge. These two entities, like theories, are *functional entities* and thus provide a common level of description for these superficially diverse aspects of theorizing. The rest of this chapter is concerned with unpacking these ideas in more detail.

Figure 4.2 gives a rough indication of how these various contexts are interrelated. The central area shows the basic relationships between framework theories, specific theories, mental models, and phenomena, as expressed in Chapter 2. Other relationships have been numbered and will be discussed below.

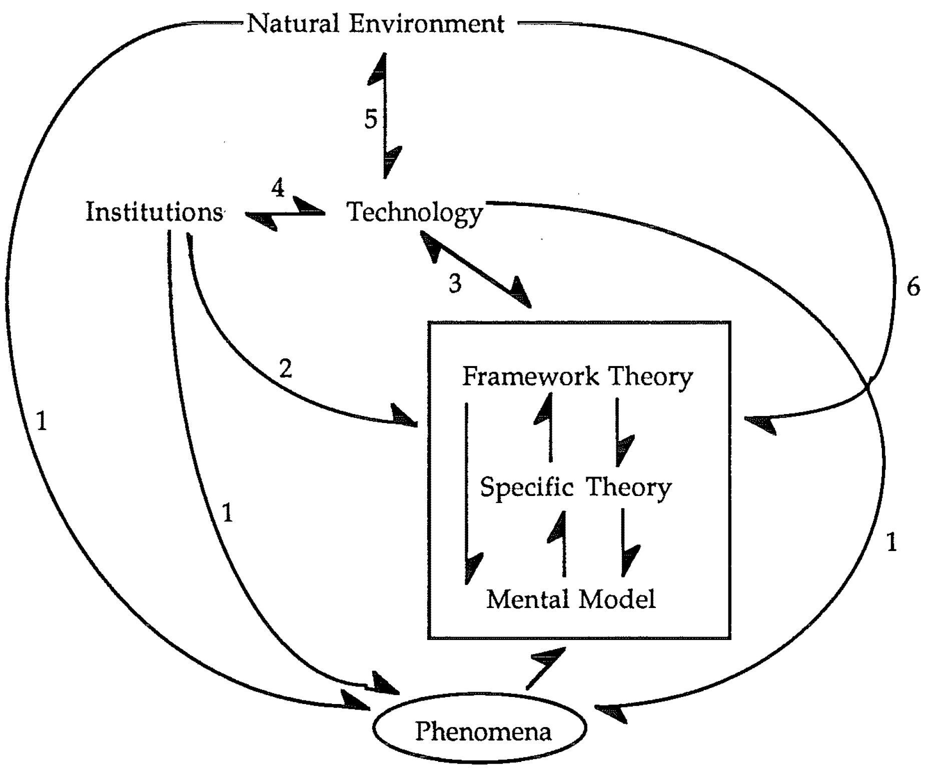

Figure 4.2
The relationship of an individual's theory system to the wider context

4.2. PHENOMENA

The phenomena that we theorize about are both natural objects and human made artifacts and activities (figure 4.2, relationship 1). Institutions provide phenomena in the form of behaviours, beliefs, and attitudes; the natural environment gives us flora and fauna, geological structures, the sky, stars, and the oceans; and technology provides us with a whole host of constructed artifacts to theorize about. Of course, these three sources of phenomena are highly interrelated. As Hooker (1985) notes much of the natural world has been shaped by humans and has become, in a sense, a technological artifact. Similarly, people are both biological organisms and institutionalized agents.

4.3. INSTITUTIONS

When Kuhn (1970: 182) utilized the word *paradigm* to mean the thing that a community of scientific specialists "share that accounts for the relative fulness of their professional communication and the relative unanimity of their professional judgments" he introduced an important social element into the study of scientific processes. A paradigm is meant to be a distinctly *scientific* entity but has been used in a vast number of contexts to mean, something like, *a shared set of beliefs and values*. Once we start talking about an entity that describes a shared set of beliefs and values we step in the territory of sociologists who have perfectly adequate names for these entities. They call them *institutions* or *social structures.*

Sociologist Anthony Giddens (1982: 10) gives us a good starting characterization of an institution:

> To speak of 'institutionalised' forms of social conduct is to refer to modes of belief and behaviour that occur and recur - or, as the terminology of modern social theory would have it, are socially *reproduced* - across long spans of time and space. Language is an excellent example of such a form of institutionalised activity, or institution, since it is so fundamental to social life. All of us speak languages which none of us as individuals, created, although we all use language creatively. But many other aspects of social life may be institutionalised : that is, become commonly adopted practices that

> persist in recognisably similar form across the generations. Hence we can speak of economic institutions, political institutions, and so on.

An institution in these terms is *not* a social or political organization like a hospital, university, church, or school, although there certainly are medical, educational, and religious institutions (Giddens, 1982: Chapter 1). Rather, an institution is a set of structured beliefs and activities. In particular I think the following features are important in the characterization of the concept of institution:

Collectivity

An institution arises out of the collective activities of a group of people. It both shapes and is shaped by the actions of individuals. Manicas & Secord (1983: 408, emphasis mine) note that

> social structure is simultaneously the relatively enduring product but also the medium of motivated human action ... Thus, social structures (e.g. language) are reproduced and transformed by action, but they preexist for individuals. They enable persons to become persons and to act (meaningfully and intentionally), yet at the same time, they are "coercive", limiting the ways we can act. It is thus that action is social, for, as acquiring the particular skills, compentencies, habits, and forms of thought presuppose human capacities, they also presuppose society in the double sense that *in acting we use and we express social structures.* Social structures are, accordingly, constituted by the motivated human acts that either reproduce or transform the very structures that are its medium ... But social structure is rarely intentionally reproduced; social change and history is the cumulative product of the largely unintended consequences of our intentional acts. People marry for psychological reasons, not to reproduce the structural form that the family takes, an unintended consequence of their acts.

Domain Specificity

Institutions are *domain specific.* That is, institutions are about specific aspects of society such as language, science, education, and commerce. Institutions, although inextricably intertwined, are about importantly different things and concern different types of activity and understanding at all but the most abstract level.

Sociologists commonly study institutions such as: the family, political-economic institutions (e.g., capitalist government), language, and science. Institutions, like theories, can be usefully divided into *framework institutions* (e.g., psychology (human nature), natural science, political economy, sociology, religion, and language) and *specific institutions* (e.g., law, family, education, physics, biology). Furthermore, specific institutions can either encompass a *topic* (e.g., the western family or western tertiary education) or a particular example of the topic (e.g., the Kennedy family, or Oxford university) (Wellman, 1990, makes this distinction with theories). This taxonomy provides us with a slightly tighter characterization than that generally offered by sociologists.

Cultural Relativity

The exact beliefs and activities of institutions vary from society to society and culture to culture. For instance, the Pakeha institution of law is quite different to the Maori institution of law (Jackson, 1988).

Implicitness

As individuals we contribute to, and are shaped by, *a number* of institutions. Institutions, like cognitive theories, are *implicit entities,* or patterns of constantly interacting units (concepts in the case of theories, individuals and groups of individuals in the case of institutions). Institutions thus overlap in important ways.

Conflictual

The individuals that make up an institution *rarely, if ever,* have the same theories about how a particular domain of phenomena work and should be best understood and acted upon. Thagard (1988: 186) suggests that

> Whereas individuals are generally expected to maintain consistency and coherence in their beliefs, a community can be expected to have sharply competing views. Proponents of different theories fight it out in the journals and other public forums. This kind of competition may well be better suited to the goals of scientific research than a more monolithic approach would be, since it is difficult to predict from what quarters good new ideas would come.

The fact that individuals within an institution differ in their beliefs and actions means that an institution is usually characterized by *conflict* caused by the *resistance* of one group of individuals to the ideas and activities of another. It is a hallmark of many institutions that this resistance is suppressed by those who hold more *power* (Parker, 1989). Power can suppress resistance in a number of ways. The most obvious is via the expenditure of military and punitive political resources. Unfortunately, for the average tyrant, this method usually proves to be an impossible burden and results in revolution or the internal collapse of the institution. A better way to use power is to instil, what Marx called, a *false consciousness* in the members of the resisting groups, so that they effectively convince themselves that there is no conflict of interests and that their problems are due to something else entirely, such as their own innate laziness or lack of ability (Goodwin, 1982; Parker, 1989; McLellan, 1975; Coser, 1977). A false consciousness, in our terms, would consist of the transmission of the dominant classes' ontology, explanatory framework, and methodology into the theories of the underclasses.

It may seem sensible to suggest that there exist, along with lay theories, lay institutions. However, it is at this point that explicating the social and institutional nature of human knowing exposes a 'high level' collapse in the distinction between scientific knowing and everyday knowing. This comes about because, since the beginning of the twentieth century, scientific technologies and institutions have increasingly come to shape *both* the scientific and lay worlds (Spiegel-Rösing, 1977). For instance, a lay person's theory about the hole in the ozone layer or the greenhouse effect has been created by the transmission of scientific theories (albeit often incompletely) through advanced communication systems. Similarly concepts and ideas in psychology and sociology have filtered into everyday speech and thought through institutions such as formal education and the media, so that now it is not uncommon to hear laypeople talking about behaviour being caused by unconscious desires, or by reinforcement, or of people coming from certain social classes or acting because of their socio-economic status. Mulkay

(1977) suggests that *pure science* can be usefully contrasted with *applied science* when addressing the issue of (scientific) institutional influences on people's theories about the world. He notes

> Applied research ... is undertaken on behalf of 'laymen' [sic], that is, persons not actively engaged in research of any kind, and communicated to 'laymen', to be used for purposes other than the further extension of scientific knowledge. In contrast, the results of pure research are intended for and communicated to other researchers, to be used by them in their own pursuit of scientific knowledge. The *intellectual* procedures adopted in pure and applied research are frequently indistinguishable and the scientific results often identical.
> (Mulkay, 1977: 94-95)

There are no distinctly scientific or lay institutions or technologies. Indeed, an important part of the character of most institutions consists of the power relations between an overclass of technologists and producers of 'expert' theory (ideology) and an underclass of users and victims of that technology or ideology.

Theoretical

Institutions can be viewed as the sociocultural version of a theory. They are the vehicles for providing us with our social transmit, which, in Ruben's (1977: 109) words, is

> a portion of the collected wisdom (or values) of society in which [people find themselves. They receive] such knowledge through [their] learning contacts with others, either before [they are] able to reflect critically on what [they are] learning or often simply as a matter of fact without critical reflection, even if [they are] capable of it.

Sociologists tend to be rather vague as to what it is that is socially transmitted. The understanding of theories presented in this work provides us with a more detailed answer. An institution provides people with 1) a way of categorizing its domain (an ontology), 2) a way of explaining how things in the world relate to each other (an explanatory framework), and the ways in which we should explore and interact with that world (methodological constraints). Although an institution is typically wracked by conflict there usually exists some basic agreement on these fundamental aspects of the domain. As Hacking (1983: 7) notes, people who have a point-by-point opposition to each others beliefs usually agree on many underlying basics. Atop this basic agreement there exists a network of conflicts and disagreements. This network of conflicting relationships actually characterizes the institution. An institution, like a theory, is in permanent flux, as its groups vie to influence its ontology, explanatory framework, and methodology. A 'healthy institution' is one in which all of its participants are encouraged to think and act critically and collectively (West, 1987; Haig, 1991b). That is, where there is

> the elimination of relations of power with the activation of people's 'self activity', their independent pursuit of a free formative practice (West, 1987: 152).

Institutions influence Theories

Institutions often supply us with beliefs and values for our framework theories (figure 4.2, relationship 2). For example, the institution of modern western physics is part of the wider institution of western science. Western science is allied with other western conceptions of human nature, society, and political economy (see Spiegel-Rösing & de Solla Price, 1977). It may seem far fetched to suppose that the institution of western science can affect our everyday theories about the motion of objects. On the contrary, I hope to show that institutions play a significant role in such theories.

Intuitive physics research has revealed that women tend to be more likely to utilize an impetus theory of the motion (as opposed to classical theory) of objects than men. McCloskey and Kohl (1983) found slight sex differences in two of their experiments and concluded that this could be accounted for because more men had received physics training than women. This in itself is an indication of the concepts, explanations, and methodological constraints that dominate in the institution of western science (Shaw, 1991; Schiebinger, 1989; Fisch, 1977). The *ontology* of this institution includes the concept of the scientist as a person embracing culturally defined masculine values such as achievement orientation, independence, endurance, intellectual self-confidence, research competence and strong goal orientation (Fisch, 1977: 292). *Explanations* of women's unsuitability for scientific thinking often include innate differences (e.g. dominance of the left hemisphere [Schiebinger, 1989]), social roles and expectations of women as mothers and home keepers (Fisch, 1977: 292), and women's disinterest in things scientific. *Methodological constraints* on women entering into science in force include the gendered use of space, lack of publicity of women's scientific achievements, sexist treatment by male colleagues and staff, and sexual harassment (Shaw, 1991).

Kaiser et al. (1985) found that physics training did not account for all of the sex differences in people's understandings of the motion of objects. It is thus likely that it is not just the institution of science that determines who should acquire certain types of knowledge about mechanics. Many of the activities that may lead a person to adopt a classical theory of motion are activities that various institutions in western society deem as more suitable for men to pursue. These include activities such as the use of firearms, aircraft, and other mechanical devices.

Institutions, then, select the type of knowledge that its various groups obtain for their framework theories according to the power structures that exist within that institution. So, for example, undergraduate students at some American universities are unlikely to receive a useful, global, and critical education because the power structure of the universities is such that they are not valued as highly as post graduate students (Gimenez, 1989; Rau & Baker, 1989).

One of the most important methodological constraints institutions place on its members is whether or not people are encouraged to value deep and broad knowledge of the phenomena in the domain. University students, scientists, politicians, and people in other high paying occupations typically value deep and broad knowledge more than the unemployed or the underclasses. This is not an innate phenomenon but a byproduct of institutional stratification. And this value system is reinforced by the commensurate occupational stratification. People who work in laborious and repetitive factory jobs are not given the time nor the opportunity to extend their theories about the world. They are placed in static and unstimulating environments (without access to technology to extend their senses) which provide little in the way of interesting phenomena to theorize about. Indeed they are placed in such unstimulating and 'safe' environments (and feel as if they cannot change any of it because of the power relations in place) that the impetus for theorizing, that is, problem solving for survival, is absent.

Theories influence Institutions

The influence of institutions by theories is, given our Western reductionist and individualist philosophy of society, the least surprising relationship of the theory-institution dialectic. We need not look further than the work of Karl Marx, F. W. Taylor, Albert Einstein, Kate Sheppard, Germaine Greer, Martin Luther King, Gandhi, Te Whiti, or Adam Smith to see how personal theories have had a massive influence on institutions and societies. But it would be naive to suggest that an individual's theory can have a major social influence just because it seems a very good theory. In addition, there are numerous social and political factors that are necessary for a theory to be spread about in an influential manner. These factors include such things as fame, ability to communicate, support (or suppression) from powerful (or vocal) groups or individuals, alternative available theories, and so on.

4.4. TECHNOLOGY

Technology and Theories

Technology plays a very important role in the formulation of people's theories about the world (figure 4.2, relationship 3), particularly in modern industrialised nations, although technology per se, includes any tool, instrument, or artifact that a person utilises to alter their surroundings in order to supplement our natural evolved capacities. Technology can extend our ability to see, or hear, or communicate, speed up or automatize tasks that can be done without tools, protect us from dangerous stimuli (bright light, fierce heat), and give us the strength to move or alter things that would otherwise be unmovable. Thus, technology standardly gives us insights into a new reality (Giere, 1988: 137-140; Hacking, 1983: Chapter 11). It either directly reveals new patterns that we could not perceive before because they were too distant, too small, too inaccessible, or too dangerous for us to approach (e.g. via microscopes, telescopes, computer enhanced images, and so on), or it saves us time and resources which we would have to expend if we relied in our natural abilities (e.g. shelter for safety, books for retaining memories, and so on). These new patterns provide us with new data for constructing our theories.

Gerd Gigerenzer (1990) suggests that within psychology the technology and tools used in our research actually become part of our theories about human thought and action. So that, for instance, Harold Kelley (1967) thought people did 'naive ANOVAs' in their heads when thinking about the world. Other common technological metaphors in psychology have included the steam engine (Freud), the telephone switchboard (early cognition), and of course the computer. Technology, thus, 1) provides new avenues for observing the world, and 2) supplies us with interesting new models for developing theoretical concepts.

Technology and Institutions

Technology also embodies both the institutional and theoretical knowledge that is required to create it (figure 4.2, relationship 4). The world we see is a world constrained by our technology's power to expose it, and our technology's power to expose the world is largely dependent on the assumptions about the world implicit in the construction of that technology. So, for instance, the electron and the proton (see Hacking, 1983 and Giere, 1988 respectively) have become tools in the creation of new theoretical subatomic particles. The nature of theoretical entities like quarks embody within them beliefs about the proton, because the construction of particle accelerators and cyclotrons is based on our knowledge of things like the charge and mass of protons (Giere, 1988: 140). Our view of quarks would be different if our view of protons was different. In a sense then, our technology is a physical manifestation of our values and beliefs about the world, and in this day and age those values and beliefs are by no means all positive. Susantha Goonatilake (1984: 121) notes that technology "reflects the class relations of a particular society, the nature of its economic system, its patterns of conflict and conflict management."

Thus, the existence of nuclear weapons as a solution to the problem of conflict, the use of drift nets as a cheap and easy solution to collecting fish, the construction of massive supertankers to transport vast amounts of crude oil, are all examples of technology instilled with the values of high yield, low cost, short sightedness, and disrespect for the finite resources of people and the world.

Since technology embodies the values of our theories and institutions, the introduction of technology into a society acts as a 'social gene', often transplanting the institution values and conflicts of the technology's society of origin (Goonatilake, 1984: 122). For instance, the introduction of mass production and privitization technologies into Africa and South-East Asia has resulted in the expansion of the capitalist free market and its allied specific institutions (such as international banks, the English language, unemployment, and Western science) into the Third World (Sardar & Rosser-Owen, 1977; Ellwood, 1990; Rose, 1988; Goonatilake, 1984: Chapter 6).

Technology and the Natural Environment

Technology has also had massive effects on our natural environment, supplying us with a whole host of new, and often problematic, phenomena for people to theorize about (figure 4.2, relationship 5). Hooker (1985: 188) notes that

> The fact that science is remaking the world around it hardly needs emphasizing. From our impact on the global climate, forests, ocean ecologies, hydrology, and so on to the explosion of urban megalopolises, manmade [sic] agricultural species and electronic communication networks, and in a hundred other like ways, science-based and -organized technological development has

> been transforming the biophysical world in quite dramatic ways into a human artifact in new patterns. These patterns have not been universally approved, far from it, but they are human designs nevertheless.

Since technologies often reflect the values of the institutions that gave birth to them we must constantly subject our institutions to critical analysis in order to ensure that we do not construct environmentally destructive technologies. The technocratic attitude that engineers and technologists simply produce the technology and have no moral responsibility for its effects on people and the environment cannot and should not be upheld by the scientific community.

> Professional engineers are acknowledged designers, advisers and construction experts. In order to maintain this elevated position they need to re-emphasise their advisory role to the public and their advisory responsibilities to the profession itself. Engineering is not free of social or political bias. Professional engineers cannot simply present their opinion and depart (Shaw, 1990: 69).

Technology, then, can no longer be viewed as a value-neutral aspect of human existence. Technology is used to shape, not only our environment, but also our societies and our personal theories about the world. Technology brings with it new windows onto the world. We must make sure that these windows do not serve to oppress people or destroy our natural environment.

4.5. EVOLUTION

There is no doubt that the natural environment has a vast influence on our social and cognitive processes (figure 4.2, relationship 6). From an ecological perspective human beings are subsystems within ecosystems and have evolved in a reciprocal way with that environment.

> Adaptable species do not only passively adapt to certain environments, they also change them and thereby create new environments. Wombats dig burrows, beavers build dams. In fact, the evolutionary process has transformed our planet. For example, forests, savannahs and tundras were all

> created by evolutionary processes. Even the oxygen in our atmosphere is said to be a result of biological processes. Those species which are adapted, not to a narrow ecological niche but to a wider spectrum of environments, are also more likely to migrate and live successfully in new lands, transforming them in turn. In a dynamic interaction species change the world which in turn poses new demands on their adaptive capacities. Those who are too slow will perish, those who adapt fast enough will further increase the rate of change. This exponential growth is characteristic of evolutionary processes. Many species will earlier or later lose in the evolutionary gamble, their adaptability will not suffice. The alarming rate of species going extinct in this century provides ample evidence of the threats a continuously changing environment poses to its inhabitants. And this is the key notion of adaptability, and hence intelligence: highly adaptable species achieve their largest advantage in a dynamic environment (Hahlweg & Hooker, 1988: 106-107).

Thus, just as we leave our mark on our environment so our environment becomes deeply embedded within our human makeup. Psychologists and biologists have speculated as to the shaping effects of the environment on the physical, behavioural, social, and mental aspects of humans. The bulk of evolutionary research has focused on adaptive physical features (such as armour plating, long legs, and so on). More recently it has been realized that physical features are deeply related to behaviours (for instance, long legs are optimal for browsing foliage from treetops, developed leg muscles are used for extreme bursts of speed) and many relevant behaviours have turned out to be distinctly social, benefiting a group of organisms rather than an individual. More recently still, Cosmides and Tooby (1987), and Shepard (1984; 1987) have suggested that it is important to speculate as to how evolution has influenced the *cognitive* aspect of animal life.

4.5.1. Species Programmes

We have discussed the idea that an institution is a vehicle for transmitting a society's ontology, explanatory framework, and methodology of a particular domain. There remains a question as to whether there is a comparable vehicle for transmitting a *species'* (or phylum's, or genus') understanding of the world into our theories. Such a vehicle would be something like a *species programme* for categorizing, explaining, and focusing actions on, the world. It would be physically instantiated in the phenotype of an organism, in the structure of its modalities and motor system as well as in the geometry of its nervous system. Clearly such an entity would be common to both scientists and laypeople. The obvious mechanism responsible for the creation of this programme would be evolution by natural selection. It just so happens that a number of psychologists, biologists, and philosophers have speculated on the nature of such a functional entity (see Dupré, 1987a, for a selection of relevant papers).

In the literature I have identified what seems to be two different approaches to understanding the nature of 'biological knowledge'. One approach, pioneered by Cosmides and Tooby (1987), suggests that people have a number of innate theories about specific domains of worldly phenomena. They consider the cognitive level of explanation to be the missing link between a workable theory of how evolution may influence behaviour. The second approach suggests that people (and many other animals) have evolved processes that allow an organism to construct its own individual theories about the world. In particular, adherents in to this approach have focused on how species have *internalised* widespread, and often very abstract, regularities in the environment. Shepard (1984; 1987), for instance, suggests that many organisms have, hard-wired into their nervous systems, an innate appreciation of the rotation period of the Earth. This reveals itself in an animal's circadian rhythms.

These two approaches can be combined to give us a rough idea of the nature of a species programme. It would very likely consist of a set of innate specific theories for dealing with biologically important phenomena. That is, for dealing with phenomena that we cannot afford to experiment with by trial and error. Atop these basic innate theories would sit a set of innate system operating principles which would guide and focus personal theory construction of the 'trial and error' type. Figure 4.3 represents these ideas diagrammatically.

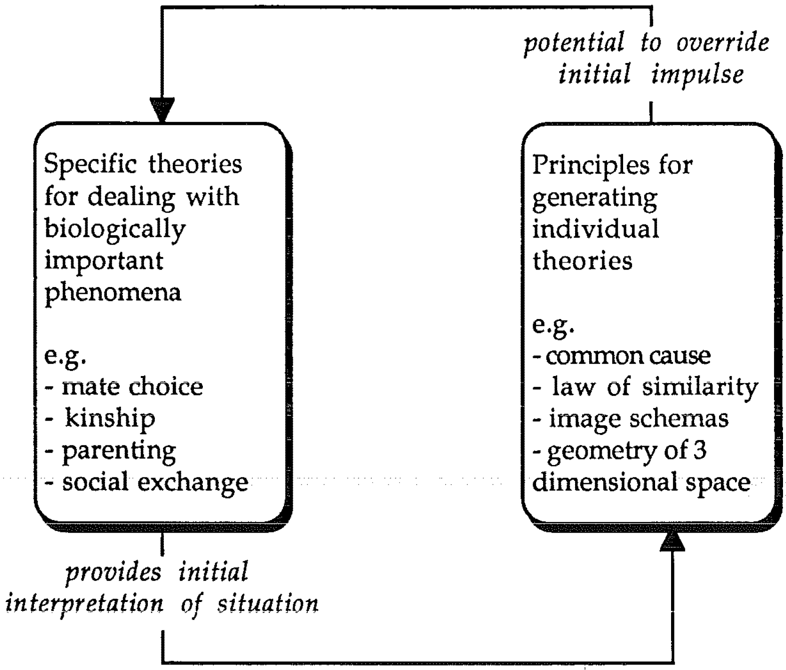

Figure 4.3
The dual function of innate knowledge in theorizing

It is clear that modern humans typically ignore the assessment of the environment afforded by many of their innate theories. However, it seems likely that they do play a significant role in some judgments.

For instance, Holland et al. (1986) speculate that biological constraints are evident in our inability to accurately gauge the acceleration of objects (which is the fundamental concept in classical mechanics). They suggest that (in evolutionary terms) the perception of acceleration has little benefit for fitness, whereas perception of velocity (that is, moving objects), something that we are relatively good at, clearly does. It seems that the intuitive theory of motion shared by many people is a theory heavily influenced by the concept of velocity.

Similarly, the apparent inability of laypeople to apply *modus tollens* in deductive reasoning exercises (Wason & Johnson-Laird, 1972) does not occur when the situation set up by the experimenter involves catching a cheat (Anderson, 1985: 267-269). Cosmides' (1985, cited in Shepard, 1987) PhD dissertation suggests that psychologists find these effects in the domain of 'lay logic' because, during the Pleistocene period, human beings evolved innate specific theories that dealt with biologically important social phenomena such as cheating within the social group.

> Success and stability of small groups of hunter-gatherers depended on the general maintenance of reciprocity in which individuals helped each other and relied upon the return of favor when it was needed. Under these long-prevailing circumstances, a sensitivity to cheaters - those who accept the benefits without paying the costs - attained a high level of development. Thus even today, nothing is more likely to engender anger than the refusal of any reciprocation by one whom we have repeatedly helped at appreciable cost to ourselves (Shepard, 1987: 253).

In sum, then, it appears that we may possess some basic, but quite specific, innate theories that encompass aspects of the world that may endanger or enhance survival. The next section speculates about the structure of these innate theories.

4.5.2. Innate Specific Theories

Cosmides and Tooby (1987) produce evidence to suggest that the hominid ancestors of modern humans were almost totally reliant on a large number of relatively inflexible innate specific theories. They note that these *Darwinian algorithms* (as they call them) served to produce mental models to deal with real life phenomena from specific domains such as aggressive threat, mate choice, sexual behaviour, pair-bonding, parenting, parent-off spring conflict, friendship, kinship, resource accrual, resource distribution, disease avoidance, predator avoidance, and social exchange. In their words, Darwininan algorithms are

> specialized learning mechanisms that organize experience into adaptively meaningful schemas or frames ... When activated by appropriate environmental or proprioceptive information, these innately specified "frame-builders" should focus attention, organize perception and memory, and call up specialized procedural knowledge that will lead to domain-appropriate inferences, judgments, and choices. Like Chomsky's language

> acquisition device, these inference procedures allow you to "go beyond the information given" - to reason adaptively even in the face of incomplete or degraded information.
> (Cosmides & Tooby, 1987: 286).

They suggest that the domains that the innate specific theories encompass include those sort of things that would be relevant to the environment in Pleistocene conditions (2 000 000 to 10 000 years ago) in which 99% of the evolution of *homo sapiens* has occured. Thus, our innate specific theories would not cover aspects of the, even relatively ancient, world, such as movement in vehicles, the use of machinery, or large scale political systems. Cosmides and Tooby note that it is likely that we have evolved the capacity to generate our own *constructed* specific theories relatively recently in our evolutionary history. This is in contrast to the popular idea that the human mind is, and has been for thousands of years, a basically domain general mechanism. Cosmides and Tooby (1987) note that the benefits of increased flexibility of this general system are tiny compared to the costs to fitness incurred by a system that requires knowledge to be verified by trial and error.

Given this point of view, we can speculate that the ability to form framework theories and to create learnt specific theories complements, but does not replace, innate specific theories. The ability to create specific theories to deal with novel phenomena increases the adaptability of organisms in a rapidly changing environment. Indeed, as Hahlweg and Hooker (1988: 107) note, "highly adaptable species achieve their largest advantage in a dynamic environment."

Innate specific theories, like learned theories, comprise an ontology, explanatory framework, and methodological constraints. Although Cosmides and Tooby do not explicitly discuss Darwinian algorithms in these terms, their research suggests that these three aspects of theories are indeed important.

Ontology

According to Cosmides and Tooby (1987: 286) Darwinian algorithms "organize perception and memory". In other words, they suggest that in order for a Darwinian algorithm to work it must possess a series of concepts about phenomena relevant to a specific domain. Thus, the 'incest' algorithm that they analyze (pp. 297-298) requires concepts of 'kin' and 'nonkin'.

The structure and movements of our bodies can be viewed as providing us with a very basic ontology. To say that biological knowledge only *constrains* our knowledge of the world is misleading. In the course of our evolution, natural selection has seen fit to expose us to a particular type of world by giving us perceptual processes that open a window onto a specific *useful* (in terms of fitness) window of reality. So the ontology that our biological knowledge provides us with includes: the colours of objects (in particular, the important 11 focal colours), the macroscopic world; the distal, rather than proximal, world, a world of differing temperature, a world of moving (e.g. looming) objects, etc. This window provides a foundation for a knowledge of that world. By interacting with the world, through education and communication, and by the construction of technology, we open up new windows on this world, but these are windows that, at base, are founded on and constrained by our biological ontology. For instance, we can enter the microscopic world by looking through a microscope, but we are still looking at the microscopic world *as if it were the macroscopic world* and often we make the mistake of importing macroscopic ideas into it.

Explanatory framework

The organization of memory and perception will also require an explanatory framework in order for the organism to embed the experience of some phenomena in a wider context. An animal that hears the nearby howl of a predator will need to know that the predator is likely to attack soon. That is, the explanation of the howl is that a nearby predator (with the disposition to howl) is making it. An explanatory framework enables an animal to predict the flow of events based on "degraded information" (that is, based on the activation of many concepts based on a small amount of perceptual input).

Methodological constraints
Darwinian algorithms must "call up specialized procedural knowledge that will lead to domain-appropriate inferences, judgments, and choices." (Cosmides & Tooby, 1987: 286). In other words, these innate specific theories need to contain some plan for the actions that an organism must carry out to deal with (attend to, escape from, get at) the phenomena in question.

4.5.3. Innate Theory Generation Principles

A number of researchers have suggested that human beings share some innate basic principles which focus our theorizing processes.

The Internalization of Long Term Regularities
Roger Shepard (1984; 1987) contends that some enduring regularities of the world are likely to have constituted part of the deep innate knowledge in the brains (and bodies) of organisms for millions of years. Shepard suggests that many of the regularities that have occured on Earth throughout the history of biological evolution are likely to be 'internalised' within the bodies (perceptual, cognitive, and motor processes) of most organisms. Shepard does not make it clear what constitutes 'internalization', but it is likely that he means the evolution of a combination of cognitive and perceptual processes that give us a particular *sensorimotor window* onto the world. This window organizes the patterns of energy that we sense. So, for instance, our innate understanding of the geometry of three dimensional space gives us the automatic capacity to understand that a sequence of similar energy patterns moving across our photoreceptors is evidence of a moving object. In particular Shepard (1987: 263) notes that we automatically and innately know that "for any two positions of an object in three-dimensional space, there exists a unique axis in space such that the object can be carried from one position to the other by a combination of a translation along the axis together with a rotation about it". Shepard (1984) has conducted a number of studies with apparent motion phenomena that support

the view that, given a pair of visual stimuli shown at different positions and separated by a small amount of time, people will automatically hypothesize that they have seen a single moving object. Shepard (1984) suggests that these internal constraints on perception also serve to constrain our dreams, images, and other mental representations. Johnson (1991) has developed this idea in some detail (see below).

Shepard (1987) has studied a number of other enduring aspects of the world which humans have internalized (including the terrestrial circadian period, the three degrees of freedom of terrestrial illumination, and the metric of functional equivalence) and which provide constraints on our theorizing processes.

The terrestrial circadian period gives many animals the ability to continue their particular diurnal or nocturnal activities without the benefit of external cues such as light and heat.

Our ability to divide up the visible spectrum into eleven basic focal colours (Anderson, 1985: 317-321) is a result of the internalization of the three degrees of terrestrial illumination. According to Shepard (1987) we automatically 'score' a perceived colour on three dimensions: a light-dark dimension, a yellow-blue dimension, and a red-green dimension. Knowledge of these basic types of colours facilitates object identification. In our theorizing it may serve to constrain the nature of our mental representations.

The internalized metric of functional equivalence gives us a basis for judging the similarity of situations. Shepard speculates that similarity is based on an exponential decay function. That is, objects that differ on some sort of feature will be thought to be proportionately less similar than the difference of the features would indicate. This sort of very abstract principle would have important consequences for theorizing. In particular it would have cause a conservative categorization of entities within a theory. Only 'things' that are obvious members of a category would be admitted (or at least admitted with full membership). This, of course, would influence the nature of our theories' ontologies in a way that a linear understanding, for example, of similarity would not. This conservativeness and caution in judging the similarity of members of a certain category or concept would certainly be a useful survival device. It may mean that, for instance, an animal may shy away from a particularly large or colourful member of its own species in order to avoid a predator of similar appearance. This caution would no doubt pay off in important biological situations.

A similar line of thinking speculates about the innateness of general theorizing procedures such as retroduction. Thagard (1988: 71) notes that Charles Sanders Peirce (1839-1914), the creator of the concept of retroduction, "maintained that [retroduction] to scientific hypotheses would be impossible if nature had not endowed us with some special faculty for making good guesses." Similarly, contemporary sociobiologists have suggested that people might have evolved *epigenetic rules* for making inferences, such as hypothesizing a common cause given the occurence of two similar events (Lumsden & Wilson, 1981 cited in Giere, 1988).

Thagard (1988) himself speculates that humans probably have some basic innate principles for spreading activation and triggering inductions, and that these constraints are enough for humans to do science, to use language, and to carry out many other (biologically unimportant?) social and cognitive activities. Unlike Chomsky (1980), he does not feel that humans have a number of relatively autonomous innate modules for carrying out various different human activities.

The following section focuses on Mark Johnson's (1991) ideas about the role of the human body in knowing. Like Shepard, he speculates that humans share some basic organizing principles for our theorizing abilities, but, whereas Shepard seems to suggest that humans have internalized these principles into our nervous systems, Johnson suggests that the structure of the human body, its movements and sensory modalities, provide us with a filter that leads people to form deep, abstract, schemas for organizing and directing our theories about the world.

Knowing Through the Body

The idea that our whole body is important in all sorts of theorizing is central to what Mark Johnson (1991) calls an *image schematic view of cognition.* He argues that *all* of our knowing about the world is predicated upon our sensorimotor experiences in the world. There is a significant amount of research which shows that our cognitive structures map the world in an imagistic way. By 'imagistic' Johnson means 'in an manner similar to the way we perceive the world through our different modalities'. That is, in a continuous spatial and analogue way rather than in a discrete, componential, and propositional way. He thus sides with people such as Stephen Kosslyn, Roger Shepard, and Philip Johnson-Laird, in arguing that images comprise a important type of mental representation that cannot be reduced to propositional statements without losing some important *procedural* capabilities. Ronald Giere (1988: 136) supports such a view when he notes that

> humans, by virtue of their biological evolution, have a highly developed capacity to represent spatial relationships. This capacity is located in the preverbal parts of the brain, closely connected with the motor control system. The overwhelming tendency among experimental nuclear physicists to think and communicate in terms of diagrams suggests that they are tapping these sorts of preverbal cognitive and sensorimotor capacities.

This emphasis on the role of perceptual images in cognition makes a lot of sense when we consider the evolution of the human mind. Our ability to represent has arisen from the need to model the perceived environment so that we can 1) avoid noxious things before we bang into them and 2) find useful things in a systematic way. In order to do these things we need to represent ourselves in a wider physical context and create plans for moving ourselves about it (see Johnson-Laird, 1983: Chapter 15). Johnson (1991) holds that it is just these movements about a physical environment that underlie all of our thinking. Thus, in a sense, all of our cognition is implicated in our perception of the movement of our bodies in the physical world. He has isolated an number of *image-schemas* which expound this idea. An image schema is an abstracted pattern that emerges through our sensorimotor activity "as we orient ourselves spatially and temporally, direct our perceptual focus for various purposes, move our bodies as functional unities, and manipulate objects to accomplish our ends." (Johnson, 1991: 8). Image schemas are, in the terms of this work, extremely abstracted problem schemas. They are innate insofar as the biology of our bodies is responsible for their existence and nature. Johnson catalogues a number of these image schemas such as the SOURCE-PATH-GOAL schema, the CONTAINER schema, and the ITERATION schema. He characterizes the CONTAINER schema in the following way:

> We experience physical and bodily containment in every aspect of our lives, and this provides imaginative structure for our understanding of all sorts of abstract containment. Whether in two or three dimensions, a container consists of an interior, a boundary, and an, exterior.
>
> Whether we are *in* bed, *in* a house, *in* love, *in* a club, or *in* the middle of a race, we experience and understand each of these situations by means of an imaginative schema of containment.
> (Johnson, 1991: 13).

Johnson goes on to note that image schemas are used literally (i.e. of things that we actually perceive) and metaphorically (i.e. of things that we cannot perceive, such as functional relationships). For instance, he provides a detailed analysis of how the CONTAINER schema can be used to explain aspects of formal logic such as the *law of the excluded middle* and the *law of non-contradiction* (see Johnson, 1991: 13-14)

Johnson argues that all of our abstract linguistic, mathematical, and logical forms of reasoning are founded on this imagistic process. This is in marked contrast to the dominant reductionist approach in the cognitive sciences, of reducing many aspects of cognition to elementary functional primitives (such as symbols and propositions), and holding that these are of primary interest and combine to form the higher analog-type forms of representation. Johnson says that this view turns the reality of the situation on its head - our image-type cognition has given rise to the functional primitive approach, not the other way around.

In summary, Johnson (1991) shows that scientific *and* everyday theorizing are predicated upon the same sort of structures and processes. Both types of theorizing rely on image-schemas derived from our sensorimotor activities in our environment.

Conclusions about Innate Knowledge

The idea that innate knowledge plays a significant role in human theorizing is one widely accepted by many cognitive and social scientists. The answer to the question of just how evolution can literally 'put ideas into our heads' is more speculative. Certainly the structure of the human nervous system, sensory organs, and motor abilities, are all subject to the shaping effects of natural selection. Modern biology has a good grasp of how physical and physiological aspects of organisms adapt to their environments. Just how evolutionary theory can be extended to encompass *functional phenomena* such as cognition and society is a question that is only now being debated by biologists, cognitive, and social scientists.

What I hope to have shown in the preceding section is that the evolved structure of our bodies has a significant effect on the structure of our theories about the world. All humans, scientists and laypeople alike, possess these structures and all humans use them in a variety of ways.

4.6. THE RATIONAL AND THE NATURAL

Knowledge has traditionally been viewed as something, static, linear, propositional, sentential, and serial (Johnson, 1991) acquired and utilized by an autonomous individual (Parker, 1989). As often as not, knowing has been viewed as an activity suitable only for an intellectual élite. Rationalized epistemologies have often talked about pieces of knowledge as if they were dictionary-like entries secured in spaces in our minds. For a long time there has been a bias toward the existence of pure reason, of knowledge as a purely cerebral (and linguistic) activity, and this bias has been reproduced in society often setting apart the wealthy ruling class of thinkers and intellectuals apart from the underclass of 'doers'. Hacking (1983), for instance, notes that the history of science glorifies theory and theorists and downplays experiments and experimentalists. He compares his attack on the intellectual élite of theorizers with Marx's emphasis on the importance of human labour power (praxis) and its grounding in the real, material world. For Hacking and Johnson (1991: 7) the emphasis on a "transcendent, disembodied rational ego" is responsible for many of the philosophical muddles that thinkers have got themselves into over the centuries. In particular, Hacking and Johnson argue that the ubiquitous problem of substantiating a link between the internal mental world and the external physical world is a product of an unwillingness to admit that knowledge is a thing for doing things in the physical world, not an abstract autonomous thing in itself. For the adherents of *naturalized epistemologies* there is no *autonomous* internal mental world, but only a system for dealing with the one 'external' reality. All of our thoughts, ideas, and emotions are anchored in our environment no matter how abstract or fantastic they may seem. Thus, the view that scientists have a privileged means for collecting true knowledge becomes questionable. The empiricist view of science loses much of its gloss when we begin to realise that the so-called objective processes of logic and mathematics are the result of social and biological mechanisms. The distinction between laypeople and scientists lies, not in the allocation of rationality to science, and social and emotional bias to non-science, but in the study of the differential treatment given the two groups by social institutions.

The new view of knowing discussed in this chapter is, as Mark Johnson (1991: 8) notes, of "an active transforming of problematic situations that helps us better understand ourselves and our world and helps us pursue our mutual interests and ends." The new view of knowing is an approach that explicates knowing, whether done by a professional scientist or a layperson, in terms of our nature as individual, social, and biological creatures.

5

Conclusions

We should be on our guard not to overestimate science and scientific methods when it is a question of human problems; and we should not assume that experts are the only ones who have a right to express themselves on questions affecting the organization of society. (p152).

*Albert Einstein, (from **Ideas and Opinions**).*

The point of this thesis has been this: psychologists have been keen to point out that laypeople theorize about the world, but that their intuitive theories are fundamentally flawed and inaccurate. Put another way, psychologists have found the structures and processes used in science to be useful metaphors for illuminating the knowing activities of laypeople. At the same time, however, psychologists have been reluctant to endorse everyday knowing as a roughly scientific activity. My contention has been that in order to make sense of the layperson-as-a-scientist metaphor, we not only need a detailed conception of the thinking processes of laypeople, but we also need to have a developed understanding of scientific cognition. My argument has been that psychologists have paid primary attention to the former while largely ignoring the latter.

Psychologists, especially those brought up in the North American tradition, have been overwhelmingly subjected to an empiricist view of science. Some, with a critical interest in science have a passing familiarity with constructionism. On the whole, however, psychologists have been brought up on a diet of observational statements, hypothetico-deductive method, Fisherian statistics (which includes the concepts of the control group and randomization), and operational definitions, unaware that the philosophy inherent in these aspects of science is a strongly empiricist one. It is not surprising then, that science, according to many 'naive science' researchers, has tended to be empiricist science.

The aim of this work has been to delve more deeply into the area of scientific cognition in order to make more sense of the layperson-scientist relationship. What I have found is this:

1) There seems to be two major foci of research in scientific cognition: the study of the nature and structure of *theory* and the study of scientific *method*. Clearly, then, any study of 'naive science' must make detailed reference to both of these aspects of scientific knowing.

2) The philosophy of science that seems to offer the best explanation of the scientific process is evolutionary naturalistic realism (ENR), which is a particular form of scientific realism. ENR takes theories to be natural, social and cognitive entities that often posit the existence of unobservable mechanisms. Their prime focus is to say something about the structures and processes that exist in the *real* world. They are not merely convenient fictions for solving puzzles or linking observational statements. Instead they are entities that aid our survival in changing environment by helping us to *explain* puzzling phenomena.

ENR also pays significant attention to scientific method, that is, the processes involved in the construction of theoretical entities. My interpretation of ENR has been to suggest that theories evolve in biological, social, and individual contexts. In particular, theories seem to evolve following a retroductive method in which our knowledge about the world is increased by descriptive and, more importantly, explanatory inference. This inference is regulated by our own particular views of the way the world is, by social and institutional contexts and by our biological makeup. This view of knowing thus transcends the empiricist view of knowledge which takes knowing to be a rational individualistic process.

Given this conception of science we are in a better position to draw parallels between scientific cognition and lay cognition. As I have demonstrated, I think that the two activities are remarkably similar.

Theories

Both scientists and laypeople construct theories. Theories are personal mental representations of some aspect of the environment. There is no requirement that theories be explicitly stated or written down to attain genuine 'theoryhood', although these *social* activities are certainly vital to the conception of modern science (Karmiloff-Smith, 1988: 184-185). Instead, I take theories to be implicit entities that arise from the activation of a number of related concepts, rules, and problem solutions. They are not concrete or 'finished' entities. Indeed, theories can be characterized by their continually changing and adaptive nature. Both scientists and laypeople possess and utilize these entities. Scientists tend to use them to characterize detailed aspects of the world. This requires the scientist to be rigorous and conceptually precise. Without these qualities scientist's theories would not be useful for the explanation of the phenomena that they represent. Laypeople, on the other hand, have broader and fuzzier conceptions of worldly phenomena. This is partly to do with the fact that laypeople do not often need to have conceptually precise knowledge for dealing with their environment, and partly to do with the fact that laypeople often do not have the time or resources necessary to develop their theories.

Methods

Since the time of the ancient Greeks many great thinkers have attempted to construct esoteric rituals that will result in great thoughts. Put another way, philosophers have sought an objective and rational method of theorizing that would provide purer knowledge than that commonly accessible by our natural abilities. It is only relatively recently that many philosophers have started to adopt a broadly naturalistic approach to epistemology. That is, they have begun to view scientific methods for constructing theories as natural activities.

In Chapter 3 I advocated the naturalistic method of retroductive explanatory inferentialism (REI). I like to think of REI as a broad characterization of human reasoning. REI is, thus, not a distinctly *scientific* process. Although REI is a process common to both scientists and laypeople, it does not follow that laypeople should construct theories identical to those constructed by scientists, for REI is extremely content-dependent. Our knowledge of the world actually regulates our retroductive inferences. Scientists tend to know different things about the world compared to laypeople. It thus follows that scientists will generate different theories about the world to laypeople.

I suggested that the concept of expertise was a useful one when examining differences between scientists and laypeople. Because of their familiarity with particular aspects of the world, scientists develop sophisticated conceptions of certain domains. Scientists do not learn to use a new type of rationality. On the contrary, they think just the way they always have, but their strategies and techniques change with the reconceptualization of the phenomena they are dealing with. To a professional sociologist, for instance, the news that a government is intending to drop taxes in favour of introducing charges for a public service may result in extreme consternation. To a layperson who does not use the service in question the news may be greeted with enthusiasm. The differing viewpoints have nothing to do with the sociologist being more rational than the layperson, but rather they are due to the fact that the sociologist sees *beneath* the surface of the situation and has some conceptualization of how such moves may be related to such things as inequality and oppression. This ability to see the underlying mechanisms at work in the situation comes from familiarity with the domain, its phenomena, and their causal relationships. Importantly, expertise is domain specific. The sociologist in the above example, for instance, may have no idea that the discovery of a new subatomic particle may herald the introduction of fabulous new technologies. Her expertise extends only to the domain of society. To many physicists she may appear irrational about subatomic discoveries.

The Wider Picture

All human beings have the same innate ability to understand the world. These abilities may be quite complex and involve both innate knowledge of specific biologically important domains as well as the capacity to generate new knowledge about the world. Scientists and laypeople learn a lot from just perceiving their own movements about the world. We detect abstract regularities and patterns which form important image-schemas. These schemas provide both laypeople and scientists with important structures for constraining our retroductive inference. The CONTAINER image-schema, for instance, stops us from reasoning that a small thing can be both inside and outside a container at the same time. Such an insight may sound extremely unexciting, but without it our thoughts about, and actions in, the world would be significantly different.

Although laypeople and scientists have the same basic biological capacities for theorizing they are subject to differential treatment within social institutions. Social institutions are simply world-views held by a group of people about a particular domain. An institution is constantly in flux as different subgroups vie to influence its world-view. Often those subgroups with more power structure the institutional activities in order to enforce their favoured world-view upon the less powerful groups. In modern industrial societies scientists make up a significant proportion of the dominant group in many institutions. In other cultures and at other times preisthoods, royalty, and civil services have held similar positions. Institutions are often structured so as to perpetuate the existing power structures. So, for instance, scientists maintain their grip on 'true' knowledge because the institutional organization ensures that scientists are given the time, resources, and cooperation necessary to construct detailed theories. Laypeople, on the other hand, are often forced into social and economic positions which preclude them constructing their own theories which may aid in their emancipation. Not all scientists, however, find themselves supported by institutions. Indeed, those who persist in advocating radical theories that may upset the present balance of power, often find their support and resources significantly curtailed. For instance, the institution of North American psychology cautions against the teaching and publishing of theoretical research, the results of which could change the structure of the institution (Wachtel, 1980; Meehl, 1972; Cattell, 1988).

However, with constant critical analysis of our institutions it should be possible to shape societies in which scientists and laypeople can strive together to construct accurate, non-oppressive, and non-destructive theories about the world. Here, I think, is perhaps the most important point of this work, which is, that we need to think critically about the implications of making sharp distinctions between scientific and lay cognition. We must be careful not to view these distinctions as natural and inevitable. Rather, we should always be on the look out for the way in which these distinctions could be the result of social processes, processes that we can change through restructuring our institutions. I hope that the, admittedly incomplete, framework outlined here can go some way toward illuminating these dimensions of the 'naive science' programme.

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